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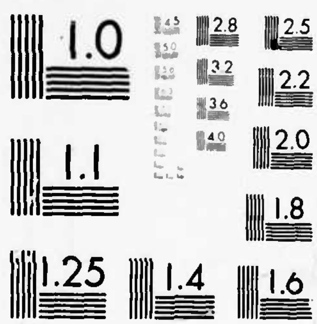

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THE AMSEC METHODOLOGY

AMSEC (Analytic Methodology for System Evaluation and Control). AMSEC is comprised of three basic components:

(1) A RMAC model which develops estimates of system or subsystem reliability, availability, and cost from real or postulated data describing the system design, the support parameters, and the plan for use;

(2) A field data transducer routine which accepts data routinely generated by the Army and converts it to RMAC model input parameters; and

(3) An executive routine which directs the RMAC model in a systematic search for optimal management actions.

AMSEC can provide a rapid assessment of vehicle and subsystem reliability, availability, and life-cycle support cost under the present framework of design, support and use parameters: it can search out improved maintenance plans, or search through alternative product-improvement programs to select a preferred course of action; it can determine the preferred times for rebuilding major components of the vehicle, or for buying new, provide estimates of optimal sparing levels for components, recommend cost-effective modifications in tactics for use: and it can determine the most cost-effective route by which to adapt to changing needs imposed by a shift from peace-time to war-time operations.

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OVERVIEW OF HANDBOOK

INTRODUCTION

The Analytic Methodology for System Evaluation and Control (AMSEC) was developed by COBRO scientists for Army use in support of management planning for major programs.

System planning rests on a framework extending from the earliest conceptual thinking to the subsequent thought processes underlying design, development, test, production, and operational use. Early ideas, once implemented in the overall planning process constrain later options as to how system development can continue. Thus it becomes important to recognize in advance the interrelationship of the myriad parameters bearing on system RMAC, and to assess the way which these parameters will eventually impact on the operational efficiency and effectiveness of the system. AMSEC permits such a predictive investigation of planning alternatives so that growth towards system objectives is accomplished with less trial and error than would be the case in its absence.

AMSEC uses as figures of merit for a system its reliability, maintainability, availability and life-cycle support cost (RMAC). By choosing appropriate definitions for these terms, the methodology can be applied to total systems or to components; to a lifetime profile of plans for use, or to a single specified mission; to overall effectiveness in meeting design goals, or to performance at different specified levels of tolerable degradation.

AMSEC can accept data which is routinely generated in the development process. This data may be inaccurate and qualitative in the earliest stages, and become more precise and quantitative as development proceeds, as tests are carried out, and as the system is fielded. The data will describe, to the level of accuracy possible at a given point in the development, the design configuration, the life characteristics and cost of the components making up the system; the maintenance and logistic support parameters; the mission profile and plan for use. From such inputs, AMSEC can be used to generate estimates of RMAC based on particular combination(s) of parameter values; to break these estimates down by system, subsystem, or component as desired, or by failure category and/or chargeability criteria; to examine the effect on RMAC of alternative changes in the way the system is designed, supported, and used; and to selectively identify that combination of changes which forecast the most improvement in system effectiveness and/or in cost reduction.

The development of AMSEC to its present computerized status has required many man-years of senior mathematical, engineering and computer programming talent It has been applied successfully to a wide range of Army systems (e.g., the CH-47, UTTAS, and AH-1G helicopters and advanced scout helicopters; the M60-A2 tank, the Gama Goat vehicle, and others) at differing stages of development, in the solution of different planning problems.

To provide a realistic representation of system behavior under use conditions the underlying mathematics for AMSEC is necessarily quite complex. A major effort has been made to keep the operational use of the methodology as simple as possible. However, the range of management problems to which AMSEC is applicable spans the entire cycle of systems development and use, and specifically includes all decisions which impact on R, M, A, or C. Table 1 identifies some of the more important of these problem areas. This wide range of management interests, each requiring a different procedure in the use of AMSEC or a different interpretation of its output has necessitated the development of a User's Manual. The purpose of such a manual is to provide each of a wide range of users with a set of defintive procedures which will allow him to direct the methodology to support effective dialogue with other disciplines and to arrive at solutions to specific problems under his cognizance.

TABLE I

MAJOR AREAS[1/] OF MANAGEMENT INTEREST RELATED TO RMAC

CONCEPT STAGE
1. Definition of system operating requirements
2. Definition of component life goals
3. Definition of mission R/A goals
4. Design approach to function implementation
5. Developer/user dialogue
6. RMAC trade-offs
DESIGN AND DEVELOPMENT STAGE
1. Definition of configuration/packaging logic
2. Preliminary maintenance plan
3. Prediction of in-use RMAC, spares
4. Assessment of design detail alternatives
5. Selection between competing vendors
6. System configuration for mission readiness, reliability, safety
7. Reliability/readiness status reports.
TEST STAGE
1. Designation of success/failure criteria
2. Definition of tests for components, system
3. Evaluation of test results, updates RMACS estimates
4. Development of maintenance strategy
5. Allocation of maintenance budget
6. Evaluation of use of condition monitoring, on-condition maintenance
7. Assessment of RAM and cost consequences of component failure by mode.
OPERATIONAL USE STAGE
1. Assessment, projection and reporting of RMAC status
2. Selection of operating tactics
3. Evaluation of ECP's
4. Selection of optimal Level of Repair (LOR) distribution

1/ The breakdown shows the development stage during which the problems identified are usually given major management attention. Obviously management concern with a given problem type transcends any arbitrary time schedule; for example the RMAC system evaluation is an important consideration at all stages.

DEFINITION OF TERMS

The value of the AMSEC output products depends upon the degree of sophistic-ation with which the user is able to define his problem and to organize his input information. The "language" of reliability analysis, in which the methodology is couched, has become quite specialized, and it is important that the user understa the significance of the input/output parameters. To this end, a glossary of term is provided, in Appendix A to this Handbook. The user is referred to this glossa and familiarity with the terms presented therein is assumed throughout the Manual Terms included in the glossary are underlined when then are initially used in the text in each chapter.

STRUCTURE AND OVERALL USE OF AMSEC

The use of AMSEC as a management evaluation and planning device is shown schematically in Figure 1. There are three basic components comprising the methodology:

1. <u>The AMSEC Field Data Transducer</u> accepts raw field data in the form generated by the Army and develops the component life and performance parameters as required by the evaluation model.
2. <u>The AMSEC RMAC Evaluation Model</u> accepts the parameters developed by the transducer, plus other parameters bearing on plan-for-use and component cost, and develops estimates of system and component RMAC.
3. <u>The AMSEC Executive Routine</u> consists of a screening and search logic for converging systematically on optimal management actions concerned with RMAC.

The first problem facing the user is therefore the determination of the necessary input parameters. These parameters are generated in three different sources which are organizationally distinct in the Army; the basic relevant data bearing on RMAC, and their sources, are identified in Figure 2. Thus AMSEC will in principle serve to integrate diverse elements of information across organizational lines, and to provide a basis for dialogue.

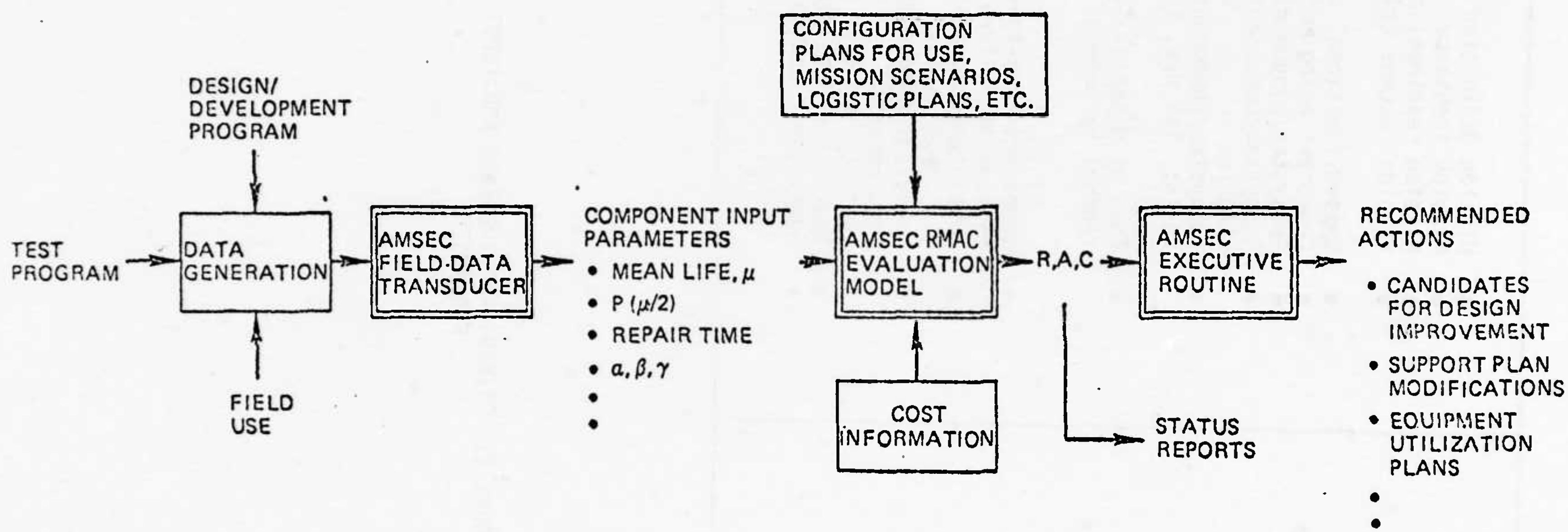


FIGURE 1
USE OF AMSEC FOR SYSTEM EVALUATION AND CONTROL

Plan for use (operations)	• Mission definition • Mission frequency • Mission readiness criteria • Mission success criteria
Hardware characteristics (engineering)	• System functional configuration • Component aging mechanisms • Subsystem/component FMEAs • Subsystem/component maintainability measures • Subsystem/component acquisition costs: (a) new, (b) overhaul
Hardware characteristics (cost)	• Cost of material for component renewal by mode of failure
Support plan definition (maintenance logistics)	• Component time-to-renew requirements, by mode of failure • Subsystem/component inspection and test frequencies • Subsystem/component skill level requirements • Cost per man hour per skill level • Spares purchase plans • Subsystem/component LOR designation

FIGURE 2. PRIMARY REQUIREMENTS FOR INPUT DATA FOR AMSEC

The process of driving out the sensitive parameters from the data routinely generated by these different Army elements is not a trivial one, but it can be broken down into a set of defined procedures. The resources available to do this depend upon the particular parameters in question, upon the stage of development at which the problem is being analyzed, and upon the extent of documentation normally generated. For example, consider the parameters describing the aging characteristics of a component (e.g., the *A* and *B* parameters of the Weibull distr bution). At the earliest stages of conceptual planning and design, the only soli data available to the analyst is that from measurements on generically similar equipment. He may be in a position to modify these estimates in the light of his judgment of the engineering differences in the new component. The fact remains that at this stage there is often a considerable uncertainty in the values of the and *B* parameters. The analyst may indeed be more concerned in investigating a *range* of possible values to determine the consequences parametrically, and to then direct future development of that component toward the most cost-effective life characteristics. For such a sensitivity study, of course, a precise knowledge of the value of the parameter under study is not needed. However, the best available value of the *other* parameters should be used.

As development proceeds, better engineering evidence is usually generated, e.g., physics-of-failure studies, failure modes, effects and criticality analyses, bench tests, etc. Field testing of the prototype system will provide still more definitive evidence. And finally, as the system moves into actual operational use, estimates of A and B can become very precise. At the latter two stages, the AMSEC data transducer element can be used to develop best estimates of life characteristics directly from recorded field observations.

Operational plans-for-use information is often also somewhat vague in the early stages of a program, but the preliminary operational requirement documentation will usually define a rough mission statement. As the program advances these mission requirements may be more fully articulated. In a similar way the support plan parameters are usually stated crudely if at all at the concept stage, and then are refined as the program proceeds.

After the input parameters have been obtained and entered into the computer, the RMAC evaluation element of AMSEC provides estimate(s) of RMAC and spar requirements for the specific combination(s) of parameters which are entered. A single evaluation, corresponding to a single set of input values, is referred to as a "point-estimate". Each such estimate provides a multiple RMAC assessment, including values for component, subsystem, and system levels, and a timeline prediction of future RMAC behavior stemming from the "single-point" input parameters. Thus the analyst has the option of assessing the values for an immediate next mission, or of watching the progressive changes in RMAC over time due to system aging, or of focussing on the asymptotic "steady state" values of RMAC toward which the system gravitates over time. All of these options stem from the same input data.

Finally the Executive Routine develops a sequence of such point-estimate solutions, following a built-in screening and search logic, which provides a display of sensitivity of RMAC to changes in the underlying variables, and a procedural convergence on optimal combinations of parameter values as directed by the analyst.

It should be noted that the use of the three elements of AMSEC to carry out a particular type of analysis is the same regardless of the stage of development. However the input data quality may vary greatly with stage of input, as well as the particular mix of analyses which are of greatest significance to the program manager.

The inherent complexity of AMSEC can be appreciated by referring to Figure 3 showing the logic dependency of the major variables which impact on RMAC. In the simplest terms, RMAC for a system or for a component depends upon how the system (component) is designed, how it is supported, and how it is used operationally. These broad categories can be broken down into primary variables which must be considered; each of these can be further broken down into the secondary variables on which they in turn depend, the tertiary variables, etc. For example, availability for a component depends upon its repair-time distribution, among other things. Repair time, in turn, is made up of several components, e.g., time to diagnose, time to remove, time for administrative delays (awaiting supplies, etc.) and time for corrective repair. Removal time depends in turn upon, for example, the skill level of the maintainer, but it also depends upon

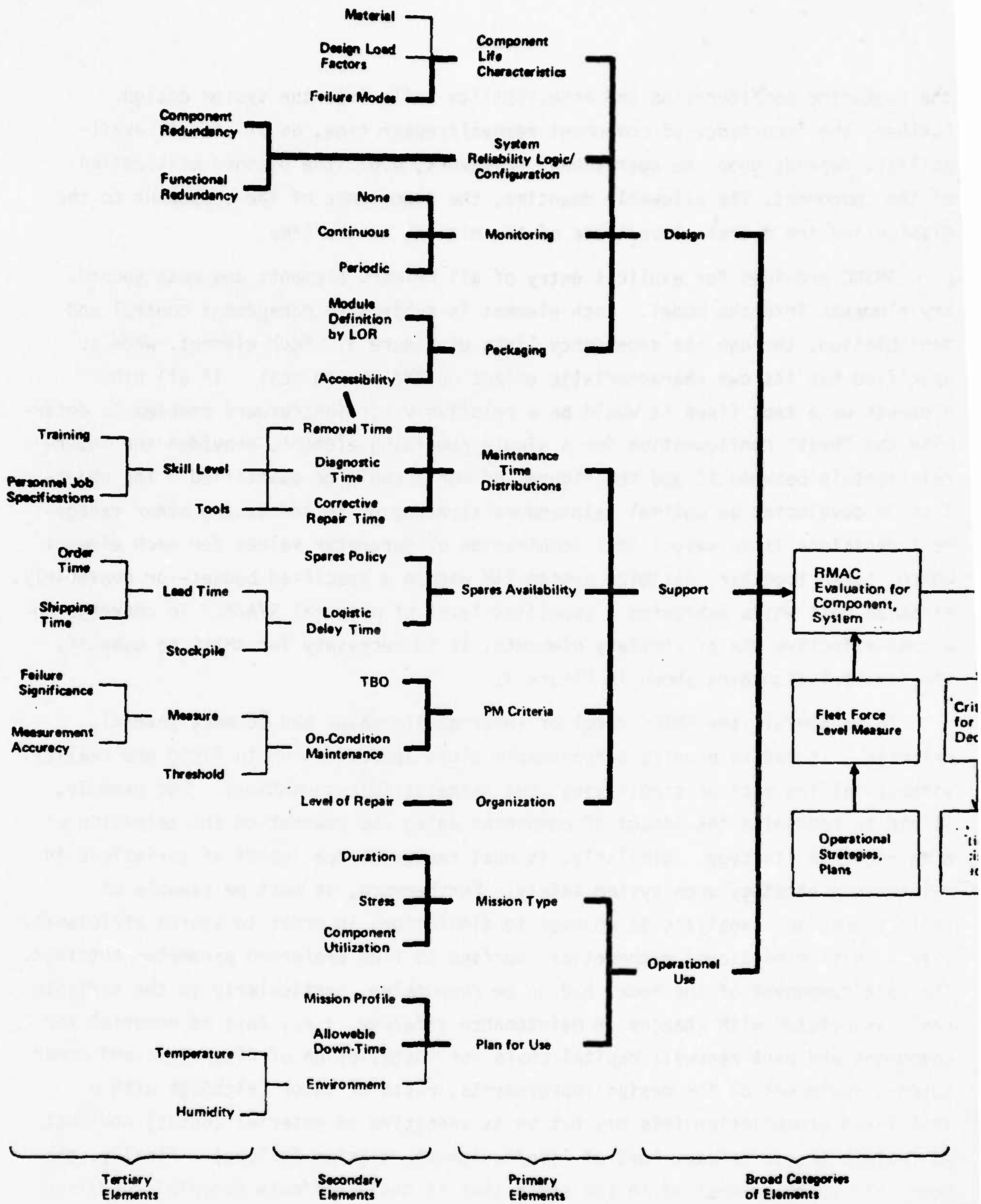


FIGURE 3. PARAMETER LOGIC FOR MATERIAL CONDITION AND COST

the packaging configuration and accessibility built into the system design. Further, the importance of component removal/repair time, as it effects availability, depends upon the operational framework, e.g., the planned utilization of the component, the allowable downtime, the importance of the component to the mission and the overall importance of the mission to the Army.

AMSEC provides for explicit entry of all primary elements and most secondary elements into the model. Each element is subject to management control and manipulation, through the dependency links of Figure 3. Each element, when so specified has its own characteristic effect on RMA and on cost. If all other elements were kept fixed it would be a relatively straightforward problem to dete mine the "best" configuration for a single remaining element, provided the interrelationship between it and the figures of merit could be quantified. The objective in developing an optimal maintenance strategy or in addressing other management decisions is to select that combination of parameter values for each element which, taken together, maximize system RAM within a specified budget--or conversel minimize cost while achieving a specified level of material R/A/M. To converge or a cost-effective mix of strategy elements, it is necessary for AMSEC to quantify the interrelationships shown in Figure 3.

To be useful, the AMSEC model of interrelationships had to meet several criteria. It had to provide a reasonably close approximation to field use realit without falling back on simplifying (but unrealistic) assumptions. For example, it had to recognize the impact of component aging and wearout on the selection of a maintenance strategy. Similarly, it must recognize the impact of variations in maintenance strategy upon system safety. Furthermore, it must be capable of rapid iteration (analytic as opposed to simulation) in order to search efficientl over a multi-dimensional mathematical surface to find preferred parameter settings The cost component of the model had to be responsive, particularly to the variable costs associated with changes in maintenance strategy, i.e., cost of material for component and part renewal; capital costs for installation of diagnostic and other support equipment or for design improvements; costs of labor (although with a semi-fixed organization this may not be as sensitive as material costs;) and cost of failure (e.g., safety, loss of life/equipment, mission failure). Finally, the model had to be predictive in the sense that it could estimate material condition and cost for parameter values outside of current practice.

AMSEC is structured to provide the interrelationships identified in Figure 3 while subject to these criteria. The heavy lines show the portions of the total planning problem which have been incorporated in AMSEC at the time of this publication. The methodology deals with different component failure modes in a completely realistic way, recognizing wearout, aging and performance degradation as well as random, catastrophic failures. It provides for a detailed definition of the design configuration, for difference in support concept and for a complete description of operational tactics. Extensions of AMSEC to deal with parameters at the tertiary level or below can be handled in modular fashion; the format of this Manual is loose-leaf to facilitate later update to the analytic capability of AMSEC.

Much of the AMSEC methodology has been computerized. Certain portions, in particular the process of obtaining input parameters, and some of the executive routines, are not yet programmed for computer use. In these cases the corresponding manual procedures have been fully documented.

ORGANIZATION LOGIC FOR HANDBOOK

The basic divisions of this Handbook fall along the lines of the three components of AMSEC, i.e.,

Section I. DEVELOPMENT OF INPUT PARAMETERS, describes the procedures involved in specifying each of the parameter values for input into AMSEC.

Section II. USE OF EVALUATION MODEL sets forth the computer procedures for generating point estimates of R, M, A, C and spares for a specified set of input parameters, and

Section III. APPLICATIONS FOR PLANNING AND DECISIONS describes procedures and executive routines for iterative use of the evaluation model to support more complex decisions.

Within each of these major sections, the subject matter is organized to deal with differences in specific treatment at different stages of the system development/use cycle, i.e.,

Chapter 1: Concept Stage

Chapter 2: Design and Development Stage

Chapter 3: Testing Stage, and
Chapter 4: Operational Use Stage

Finally within each Chapter, the major subdivisions are directed to the various problem types that are of concern to management during the specific stage of development. Each problem is viewed from the standpoint of several different users.

a. A Description of the Problem is provided which serves to identify the particular area of interest under consideration. This section is directed toward program management, and provides an overview of (a) the problems of parameter estimation which are important to program control, and (b) the decision and evaluation areas in which he can expect support from AMSEC.

b. An Analysis Procedure is presented which is directed toward the systems analyst. This describes the step-by-step procedures to be followed in applying AMSEC to the problem at hand and provides illustrative example(s) where these would be useful.

c. A Computer Programming Summary is set forth, with an Appendix, where necessary, which cross-references for the benefit of the programmer the source documentation which is available.

The organization of the Handbook is thus characterized by the following morphology:

SECTION: AMSEC COMPONENT
CHAPTER: STAGE OF SYSTEM DEVELOPMENT
Subchapter: Problem Type
Problem Description
Analysis Procedure
Computer Programming Summary

In order to accommodate each of a wide variety of users and interests, an effort has been made to keep each portion of the Handbook complete in itself. Since some of the procedures and examples are applicable at all stages of development, this approach has led to a certain amount of redundancy; however, the gain in clarity and simplicity of exposition for a reader interested in a single problem description, and the avoidance of unnecessary cross-references, were felt to justify this repetition.

SECTION I
DEVELOPMENT OF INPUT PARAMETERS
INTRODUCTION

The input parameters required for the operation of AMSEC are shown for reference in Table I.1. Full definitions are set forth in the Glossary of Terms, Appendix A.

The approach to the problem of specifying parameter values for a given AMSEC run is different depending upon whether a point-estimate of the parameter is required, or simply an operating range of values for purposes of a sensitivity analysis. In both cases, the sources of available information and the specific data collection and processing steps may differ depending on the stage of development during which the data are required.

The following pages describe the estimation process in each case.

TABLE I.1

INPUT PARAMETERS USED IN AMSEC METHODOLOGY

SYSTEM CONFIGURATION • Number of components in equipment ($\underline{n_k}$) • Number of equipments in system ($\underline{N}$) • Number required for equipment readiness ($\underline{x_k}$) • Number required for mission success ($\underline{x'_k}$)
COMPONENT LIFE CHARACTERISTICS • Number of mission failure modes (for k^{th} component) (m_k) • Number of failure stages for each mode, $S_{k,j}$ • Survival distribution (curve) for each stage, $S'_{k,j}$
COMPONENT MAINTAINABILITY/MAINTENANCE/SERVICE • Probability of handling error ($\underline{1-\delta k}$) (constant) • Renewal distribution (curve) ($\overline{\gamma_{1k}(t)}$) (preventive, initiation of action) • Renewal distribution (curve) ($\underline{\overline{\gamma_{2k}(\tau)}}$) (preventive, maintenance time after initiation) • Non-renewal distribution (curve) ($\overline{\beta_k(t)}$) • Renewal distribution (curve) ($\underline{\alpha_k(\tau)}$) (corrective) • Service frequency (f_s) • Man hours per service (h_{k0}) • Man hours per pm renewal (h_{k1}) • Man hours per Handling/Transportation (H/T) mishap ($\underline{h_{k2}}$) • Man hours per mission failure ($\underline{h_{k3}}$)
LOGISTIC SUPPORT • Component rebuild cycle (R_c) • Component protection level (spares) (Q_s) • Number of systems to be supported ($\underline{h}$) • Number of spares of the k^{th} component/equipment on hand, $\underline{W_k}$ • Lead time for spares requisition (T)
OPERATIONAL USE • Number of missions ($\underline{\nu}$) • Mission time ($\underline{t}$) • Time between missions ($\underline{\tau}$) • Component utilization factor (ρ_k) • Failure mode criticality factor for k^{th} component $C_{k,f}$

TABLE 1.1 (Cont)

COST BASIS

- Cost ($) per service man hour ($C_{k0}$)
- Cost ($) per PM man hour ($C_{k1}$)
- Cost ($) per CM man hour ($C_{k2}$) for handling/transportation failure
- Cost per man hour for CM by failure mode ($C_{k3,m}$)
- Material cost ($) per service ($C'_{k0}$)
- Material cost ($) per PM renewal ($C'_{k1}$)
- Material cost ($) per CM renewal ($C'_{k2}$) for handling/transportation
- Material cost ($) per CM by failure mode.
- Cost ($) unavailability ($C_{\bar{A}}$)
- Cost ($) unreliability ($C_{\bar{R}}$)

CHAPTER 1
INPUT PARAMETERS--CONCEPT STAGE

INTRODUCTION

At the concept stage of development, and even in the early design stage, the system is only roughly defined; the effect of some parameters may not yet be recognized or understood, and all parameters are subject to change as development proceeds and better information becomes available. No system-specific tests have been carried out, and the only firm information about the system is in the form of preliminary requirements and specifications. Corollary data may, however be available for generically similar systems or components which have already been designed, tested and operated.

Operational and support plans are also likely to be poorly defined, usually based on a set of "requirements" which are admittedly planning values and which may even be internally inconsistent.

Procedures for parameter estimation at the concept stage provide for the preparation of a check-list of available sources of information, a formalized routine for extracting the best data possible from those sources, and the establishment of criteria for ranking the quality of the data.

It is important to recognize that the process of parameter estimation at the concept stage establishes target values which are considered reasonable. The interrelating of these estimates into an RMAC sensitivity analysis during concept can be of major value, since the analyst usually has much greater

flexibility in selecting parameter values to obtain the most cost-effective combination. The analysis at this stage serve to aim the overall development program in the general direction of optimality, so that early gross errors can be avoided and future refinements in program thrust can be more readily made as new information becomes available.

DETERMINATION OF SYSTEM CONFIGURATION PARAMETERS: POINT VALUES

Problem Description

The problem facing the analyst is to obtain the most accurate possible statement of each of the system configuration parameters, based on the totality of available information. The sources of data available at this stage of development are quite limited. They may include any or all of the following:

- Documentation of system operating requirements.
- Engineering or Project Management (PM) studies of conceptual approaches--e.g., component packaging and support schemes; reliability block diagrams; component life parameters.
- Preliminary cost information.
- Documentation on generically related systems.
- Contemporary engineering judgment.

The specific subsystems which are required for a mission and the amount of redundancy depends both on the complexity and rigor of the mission and on the interest which the analyst has in achieving maximum performance, or in compromising on lower levels of performance, and on the emphasis of safety.

A structured survey of the available sources, and an objective synthesis of the data contained therein, will provide a current "best estimate" of the configuration parameters, $\underline{N}$, $\underline{n_k}$, $\underline{X_k}$, and $\underline{X'_k}$ for each type of mission assignment, and will define the interrelated reliability logic for all components comprising the system.

Analysis Procedure

1. Obtain existing documentation of system from system proponent, TRADOC and/or from the cognizant PM as available.
2. Obtain documentation on related systems from appropriate PM and/or from operating Army agencies.
3. Obtain results of any conceptual or pre-design studies from PM.
4. Bring forward mission requirements and performance thresholds of interest from analysis of operational parameters (see page 34).

5. Conduct engineering discussions with cognizant PM engineers. Factors to be considered in engineering discussions of the configuration parameters include constraints imposed on R,M,A or C; space and weight constraints; failure modes, effects and criticality.
6. Prepare matrix of sources vs. configuration data elements, and enter estimates for maximum capability missions; prepare a similar matrix for reduced capability missions and for safety (see illustrative Figure I.1).
7. Prepare estimates of priority to be assigned to the different sources, and enter on work-sheet.
8. Enter selected value of each parameter in right column. This will normally be the value corresponding to the highest priority source. If another value is used enter reason for such selection as exhibit.

Computer Programming Summary

None required.

		TRADOC	PM Study	Related Systems	Engineer Estimate	Other	Selected Nominal Value
Priority→ Subsystem: 1	n X X'						
Priority→ Subsystem: 2	n X X'						
Priority→ Subsystem: 3	n X X'						
. . . . .							
Priority→ Subsystem: N	n X X'						

To be completed for maximum capability missions, reduced capability missions, and safety, as specified by analysis criteria.

FIGURE I.1. WORKSHEET FOR DETERMINATION OF SYSTEM CONFIGURATION PARAMETERS

DETERMINATION OF SYSTEM CONFIGURATION PARAMETERS: RANGE OF VALUES

Problem Description

For purposes of a sensitivity analysis of a given variable, it is necessary to identify a range of values of interest, over which the variable could be tentatively assigned for investigation, without exceeding the bounds of feasibility. The sources of data available are essentially the same as those for the determination of point-values.

Analysis Procedure

1. Determine specific configuration variable(s) which are of concern to management for sensitivity study and optimization. Where necessary, confirm this selection with the cognizant PM.
2. Prepare preliminary definition of ranges of interest for each variable. Where the limits of practical interest are not obvious, the rule of thumb for analysis is to select a range which is too large rather than too small. Where necessary, obtain engineering guidance on the selection. Factors to be considered as bearing on practicality of parameter values are basically the same as for point estimates--i.e., weight and space constraints, system R,M,A,C requirements.

Computer Programming Summary

None required.

DETERMINATION OF COMPONENT LIFE CHARACTERISTIC PARAMETERS: POINT VALUES

Problem Description

In its operational life a component is subjected to various operational and environmental stresses which may, singly or in combination, degrade the ability of the component to perform until that ability falls below an acceptable threshold. At that time the component is said to have failed. The dominant stresses which must be considered include, e.g., operating overload; calendar time; operating time, operating miles, or rounds, and such environmental stresses as temperature and humidity. If one assumes that the system is properly used, the prevailing functional arguments for failure usually relate to the duration of the operational hazards. Failure of the component may occur in any of several modes, e.g., breaks or open circuits, excessive wear, jamming, etc.

The life characteristics of a component can be expressed in terms of the probability distribution for surviving each mode of failure, as a function of the extent of exposure to the dominant hazard(s). AMSEC provides for consideration of either one or two "stages" of hazard exposure within a failure mode. As an example, the first stage may represent the operating hours until initiation of a new major hazard, and the second stage may represent the duration of that hazard before failure. The first stage event may be (e.g.) the initial pitting of a bearing, and may be exponentially (randomly) distributed; this triggers a second stage wearout mechanism, which could be represented by a Weibull distribution, and which leads to bearing failure at the end of that stage, in the mode which was triggered.

AMSEC accepts as input the failure law for a component by mode and stage either, expressed as a two parameter Weibull distribution, or described by a curve composed of end-to-end linear segments drawn from empirical data or hypothetical reasoning. It is obvious that the linear segment curve input requires as many point (XY) pairs as there are segments. For the Weibull, two parameters are necessary. For each stage and mode, AMSEC will permit the parameters of location and shape to be input directly, or alternatively permit estimates of the MTBF and the probability that the component will survive one-half the MTBF to be inserted.

At the concept stage, the data available to the analyst depends upon whether the component is a new design or is "off-the-shelf." The problem is to investigate all possible sources of life data and develop a best estimate of the parameters characterizing the distribution.

Analysis Procedure

1. For the component under investigation, determine if it is a new design or is "off-the-shelf."
2. (a) If off-the-shelf, investigate availability of design studies or test and/or operational data. If available, follow procedures for appropriate stage of development as set forth on later pages.
   (b) If not off the shelf, or if sufficient data not available, proceed to Step 3 below.
3. Obtain existing documentation on component life requirements and/or estimates from TRADOC and the cognizant PM.
4. Conduct engineering discussions with cognizant PM engineers. These discussions should be structured, first to bracket the parameter value in question, for each failure mode, then to narrow the bracket as much as possible. Factors to be considered include any knowledge of catastrophic failure and aging mechanisms, probable stress conditions when in use, and the level of performance below which the component will be defined as having failed.
5. Prepare matrix of sources vs. life characteristics estimates by mode, and enter estimates (see Figure I.2).
6. Prepare estimates of priority to be assigned to different sources, and enter on worksheet.
7. Enter selected value of each parameter in right column. This will normally be the value corresponding to the highest priority source. If another value is used enter reason for such selection as an exhibit.

Computer Programming Summary

None required.

	Data Source														
	TRADOC			PM Study			Engineer Estimate			Other			Selected Nominal Value		
	Mode 1	Mode 2	Mode 3	Mode 1	Mode 2	Mode 3	Mode 1	Mode 2	Mode 3	Mode 1	Mode 2	Mode 3	Mode 1	Mode 2	Mode 3
Component 1															
Source Priority															
Stage 1															
Parameter 1															
Parameter 2															
Stage 2															
Parameter 1															
Parameter 2															
Component 2															
. . . .															
Component 3															
. . . .															
Etc.															

FIGURE I.2. WORKSHEET FOR DETERMINATION OF COMPONENT LIFE CHARACTERISTICS

DETERMINATION OF COMPONENT LIFE CHARACTERISTIC PARAMETERS: RANGE OF VALUES

Problem Description

For purposes of a sensitivity analysis of a given variable, it is necessary to identify a range of values of interest, over which the variable could be tentatively assigned for investigation, without exceeding the bounds of feasibility. The sources of data available are essentially the same as those for the determination of point values.

Analysis Procedure

1. Determine the specific life/mode variables which are of concern to management for sensitivity study and optimization. Where necessary, confirm this selection with the cognizant PM.
2. Establish preliminary definition of ranges of interest for each life/mode parameter of interest. Where the limits of practical interest are not obvious, the rule of thumb for analysis is to select a range which is too large rather than too small. Where necessary, obtain engineering guidance on the selection. Factors to be considered as bearing on practicality of parameter values are basically the same as for point estimates--i.e., aging and catastrophic failure mechanisms, and problem use conditions.

DETERMINATION OF COMPONENT MAINTENANCE/MAINTAINABILITY PARAMETERS: POINT VALUES

Problem Description

The maintainability of a component describes the ability of the maintainer, of specified skill level, to detect and diagnose a failed component, and to take the appropriate replacement/repair actions. Design feature such as accessibility and monitorability must be considered, as well as availability of skills, specialization of tools and equipment required, and training capability. Relevant maintainability parameters include α, β, γ_2, δ, and h. The parameter $\gamma_{2k}(\tau)$, the distribution of removal/repair time once action is initiated,(γ_{1k} composed of several sub-elements, e.g., time to inspect, time to diagnose, time to remove/replace, time to repair, and gap times while waiting for parts, for appropriate skills or for tools. Relevant maintenance parameters deal with the features of policy (e.g., γ_1, f_s) and the status of skills, tools, and equipment provided.

At the concept stage, the data available to the analyst depends upon whether the component design is new or its interface with the system different. It also depends upon whether the system will be used in a substantially different environment than corresponding systems with similar components. The problem is to investigate all possible sources of maintainability data and develop a best estimate of the parameters identified above.

Analysis Procedure

1. For the component under investigation, determine if it is a new design or is "off-the-shelf."
2. (a) If off-the-shelf, investigate availability of design studies or of test or operational data on maintainability. Relevant MEA data are among the first documents to provide estimates of these parameters and should be investigated. If such information is available follow procedures for appropriate stage of development as set forth on later pages.

   (b) If not off-the-shelf, or if M data are not available, proceed to Step 3 below.

3. Obtain existing documentation on component maintenance/maintainability requirements and/or estimates from TRADOC and the cognizant PM.
4. Conduct engineering discussions with cognizant PM engineers. These discussions should be structured, first to bracket the parameter value in question, then to narrow the bracket as much as possible. Factors to be considered in such a discussion include the skill levels which will be available, the environmental conditions under which maintenance will be carried out, and system operating schedules (e.g., allowable down time, etc.). For a preliminary estimate, with no supporting data, values of $\alpha=1$, $\beta=0$, $\gamma_1=1$, $\delta=1$ may be used a priori. An estimate of the mean value of $\gamma_2(\tau)$ may be used.
5. Prepare matrix of sources vs. maintainability/maintenance curves and/or parameters and enter estimates (see Figure I.3).
6. Prepare estimates of priority to be assigned to different sources, and enter on worksheet.
7. Enter selected value of each maintainability/maintenance curve or parameter in right column. This will normally be that corresponding to the highest priority source. If another value is used enter reason for such selection as an exhibit.

Computer Programming Summary

None required.

	Data Source				
	TRADOC	PM Study	Engineer Estimates	Other	Selected Nominal Value
Component 1					
Source priority					
$\alpha(\tau)$ 1/					
$\beta(t)$					
$\gamma_1(t)$					
$\gamma_2(\tau)$					
δ					
h_0					
h_1					
h_2					
h_3					
$h_{4,m}$					
f_s					
Component 2					
.					
.					
Etc.					

1/ All terms defined in Glossary, Appendix A.

FIGURE I.3. WORKSHEET FOR DETERMINATION OF COMPONENT MAINTAINABILITY CURVES AND/OR PARAMETER VALUES

DETERMINATION OF COMPONENT MAINTENANCE/MAINTAINABILITY PARAMETERS: RANGE OF VALUES

Problem Description

For purposes of a sensitivity analysis of a given variable, it is necessary to identify a range of values of interest, over which the variable could be tentatively assigned for investigation, without exceeding the bounds of feasibility. The sources of data available are essentially the same as those for the determination of point values.

Analysis Procedure

1. Determine the specific maintenance/maintainability variables which are of concern to management for sensitivity study and optimization. Where necessary confirm this selection with the cognizant PM.
2. Establish preliminary definition of ranges of interest for each parameter of interest. Where the limits of practical interest are not obvious, the rule of thumb for analysis is to select a range which is too large rather than too small. Where necessary, obtain engineering guidance on the selection. Factors to be considered as bearing on practicality of maintainability parameter values are basically the same as for point estimates--i.e., the skill levels available, range of environmental conditions, allowable down times.

DETERMINATION OF LOGISTIC SUPPORT PARAMETERS

Problem Description

The logistic complex which supports a fleet of operating systems is comprised of an entire chain of functions, from production and acquisition to shipping, storage/inventory, handling, inspection and preparing for use. These functions all have as their ultimate objective the supplying of necessary components, equipment and skills to keep this fleet in a required state of readiness. The figures of merit for the logistic system are:

a. The probability that no unit of the fleet is in an unavailable state because of lack of skills or replacement components, over a specified period of time, and

b. The cost of the logistic system allocatable to the fleet under consideration. This cost, ultimately, is one component making up the material cost of components (i.e., cost = cost of production plus cost of delivery).

The top-level parameters describing the logistic complex are:

a. The number of systems in the fleet to be supported (h).

b. The number of spares for the k^{th} equipment which are on hand or would be available as needed ($\underline{W_k}$), and

c. The statistical protection level which is required for the fleet ($\underline{Q}$).

The three parameters are interdependent, so that if two are given, the third can be calculated through AMSEC. Normally the parameters which are required as input are h and Q, with AMSEC providing an estimate of the spares required for each component, in order to provide the specified level of fleet protection.

Analysis Procedure

1. Discuss with TRADOC the probable range of fleet sizes (h) which are of operational interest to the Army. Factors to be considered include

current deployment tactics, rate of acquisition, training capability.

2. (a) Select the median value for point estimates.
   (b) Use entire range for sensitivity.
3. Discuss with TRADOC or the cognizant PM the range of values for the protection level (Q) which are of interest. Factors to be considered include mission criticality, allowable delay time, ability to "cannibalize".
4. (a) Select median value for point estimates.
   (b) Use entire range for sensitivity.
5. Normally W_k will be an output value rather than an input, and will be calculated for various postulated levels of h. If, however, the logistic system is inventory limited, W_k may be specified for each component. At the concept stage a nominal value for W_k may be obtained from the cognizant PM or TRADOC. Factors to be considered include the probable MTBF for the component, and its cost, size and weight. A range of values of W_k may also be considered, as a first step toward optimizing the overall mix of W_k to obtain highest Q for a given spares budget.
6. Enter values of h, W, Q and T in tabular form for later use (see Figure I.4).

Computer Programming Summary

None required.

Data Source

Logistic Parameter	TRADOC	PM ESTIMATE	OTHER	SELECTED NOMINAL VALUE
h 1/				
Q				
W Comp 1 2 3 . . N T Comp 1 2 3 . N				

1/ All terms defined in Glossary, Appendix A.

FIGURE I.4. WORKSHEET FOR DETERMINATION OF LOGISTIC SUPPORT PARAMETERS

DETERMINATION OF OPERATIONAL USE PARAMETERS

Problem Description

The operational use parameters describe the conditions under which a system will be deployed. Particular parameters for input to AMSEC include $\underline{\nu}$, $\underline{t}$, $\underline{\tau}$, $\underline{\rho}$, and R_C. Here it is assumed that "nominal" operating and environmental stresses will hold. If these stresses fall outside of the nominal operating range, the effect will be entered through changes in the life characteristics or maintainability parameters. AMSEC can accept inputs of $\underline{\nu}$, $\underline{t}$, $\underline{\tau}$, $\underline{\rho}$, and R_C on the basis of average values, and deal with the entire span of system use over which these averages are assumed to hold.

Usually ν is considered as a running variable and component/system degradation in RMAC is estimated in terms of age measured against $\underline{\nu}$. However each variable can be considered alternatively as being fixed or variable.

Analysis Procedure

1. Discuss with TRADOC and/or cognizant PM, the way in which the system is to be used under existing concepts. Factors to be considered include:
   a. The plan for use: what frequency of missions? How long between missions? Planned service, life? Arrival pattern of missions. (AMSEC currently assumes the missions are periodic; an extension to address random mission arrivals can be added in the future).
   b. Mission type: duration $(\underline{t})$, component utilization during mission $(\underline{\rho_k})$. Mission type is currently held fixed for AMSEC; an extension to multiple mission types can be added.
   c. Criticality of mission--considered under cost of mission failure.
   d. Effect of constraints placed on A, R, C
2. Enter values for $\underline{\nu}$, $\underline{t}$, $\underline{\tau}$, $\underline{\rho}$, and $\underline{R_C}$ in tabular form for later use (see Table I.5).

TABLE I.5. WORKSHEET FOR DETERMINATION OF OPERATIONAL USE PARAMETERS

	Data Source			
Operational Use Parameters	TRADOC	PM Estimate	Other	Selected Nominal Value
ν 1/ t τ R_C ρ_1 ρ_2 . : ρ_N				

1/ All terms defined in Glossary, Appendix A.

DETERMINATION OF SUPPORT COST PARAMETERS

Problem Description

The cost of system support allocatable to a component is composed of four basic factors:

a. The cost of material, that is, the end cost of the component to the user, including costs of acquisition; delivery, storage and interim servicing; testing, and preparation for use.

b. The cost of labor ($/hr) involved in actual removal/repair activities. This includes routine handling.

c. The cost of non-routine handling for, e.g., a system that failed in use and had to be air-lifted back to depot for maintenance.

d. The cost of failure over and above the cost of replacing the failed component. This can be thought of as the cost of unreliability, plus the cost of unavailability, and may include, for example, crash damage, loss of life, or loss of a mission.

Each cost factor can be sub-categorized in terms of the particular mode of failure/removal to which the cost is applicable. The problem here is to formulate a cost profile for each component, based on these four factors, from the best available sources of information. At the concept stage, the availability of much of the relevant data will depend upon whether the component is "off-the-shelf" or is a new design.

Analysis Procedure

1. For each subsystem/component under investigation, determine if it is a new design or is "off-the-shelf".

2. (a) If it is "off-the-shelf", investigate availability of existing cost records through cognizant PM or other source. If available follow procedures for appropriate stage of development.

   (b) If not "off-the-shelf" or if cost data are not available, proceed to Step 3 below.

3. Obtain existing documentation on component cost parameters and/or estimates from PM and from Procurement.

4. Conduct discussions with the cognizant PM cost analysts and Procurement Specialists. These discussions should be structured, first to bracket the parameter value in question, then to narrow the bracket as much as possible. Factors to be considered include changes in material acquisition costs and in labor rates; changes in design modularity/accessibility for components; identification of the line or shop replaceable/repairable units (LRU,SRU); availability of special tools/equipment; delivery method to be used, and impact of component failure on safety, mission success, by mode.

5. Prepare matrix of sources vs. cost data and enter estimates (see Figure I.6). 1/

6. Prepare estimates of priority to be assigned to different sources, and enter on worksheet.

7. Enter selected value of each parameter. This will normally be the value corresponding to the highest priority source. If a different value is selected, enter reason for such selection as an exhibit.

Computer Programming Summary

None required.

1/ NOTE: Where data are available, the replacement cost of the component can be modified to show the cost as an overhaul cost/repair cost/new component cost composite, to reflect actual inventory make up.

Cost Parameter	Data Source: Procurement	AVS PM	Other	Selected Nominal Value
Source priority				
Component 1 Labor cost per man hour PM removal HT failure CM, Mode 1, 2, ..., m				
Material Cost Service PM removal H/T failure CM, Mode 1, 2, 3, ..., m				
Component 2 Etc.				

FIGURE I.6. WORKSHEET FOR DETERMINATION OF COST PARAMETERS

SECTION I

CHAPTER 2

INPUT PARAMETERS--DESIGN AND DEVELOPMENT STAGE

INTRODUCTION

During the design and development stage the system configuration becomes firmer. Specific component features are chosen, a preliminary maintenance plan is established, and dialogue with TRADOC begins to impact on downstream plans-for-use. Engineering studies are carried out, and early estimates of reliability, availability and maintainability are documented in the MEADS and related documents. A certain amount of testing is carried out at the component and subsystem level, and new full-system test plans are advanced.

From this growing mass of engineering analysis output, it is possible to review, update and gradually supplant the data obtained at the concept stage.

The procedures for parameter estimation at the design and development stage parallel those at the concept stage, the difference being that the weight of evidence is swinging away from broad statements of engineering judgment, requirements definitions and experience with generically related components; instead it is swinging toward more definitive information about the specific system itself. The PM and his contractors become the major data sources.

The problem at this point becomes one of collecting, sorting and organizing the data which become available during design and development, drawing the relevant parameter estimates from that data, and determining the relative validity of those estimates compared with those developed at earlier stages or from generically related systems.

DETERMINATION OF SYSTEM CONFIGURATION PARAMETERS

Problem Description

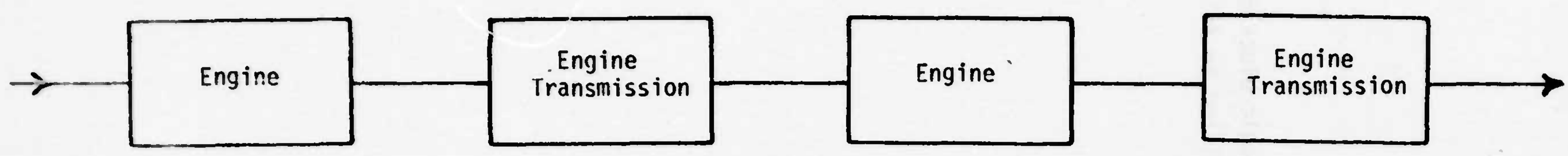
The problem at this stage is to obtain the most accurate possible statement of each of the system configuration parameters, based on the totality of information available in the often rapidly changing environment of design and development. The sources of data at this point are design drawings and functional block diagrams, engineering studies, and limited tests.

It is important that the design configuration be identified down to the subsystem/component level at which removal actions take place for repair or preventive maintenance. The specific subsystems which are required for a mission, and the amount of redundancy, depend both on the complexity and rigor of the mission and on whether the analyst is interested in maximum performance, degraded performance or safety.

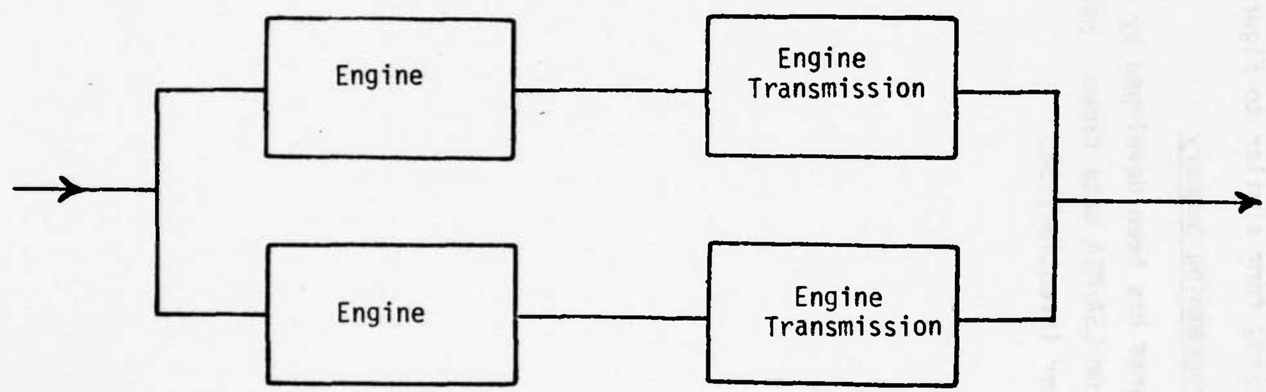
The requirement at this stage is to determine the parameter values $\underline{N}$, $\underline{n}_k$, $\underline{X}_k$, and $\underline{X'}_k$, and to define the interrelated reliability logic for the N subsystems and the n_k components, for each type of mission assignment. For a full-capability mission, for example, an aircraft with two engines will require the operational use of both, so that they would be shown in series logically. For purposes of safety, however, a single engine may be able to provide a sufficient aircraft viability, so that in this case the two engines would be shown in parallel. Other components (e.g., weapon system) will not be shown at all, if they are not required for aircraft safety under the particular missions of interest.

Analysis Procedure

1. Obtain design logic diagrams from the cognizant PM; obtain work-unit breakdown from contractor MEADS.
2. Obtain updated mission concepts from the cognizant PM or TRADOC and designate components required for different defined missions.
3. Lay out subsystem reliability/availability block diagrams for different missions. Group into major functions, each of which is required for the specified mission and thus are in series logically. Indicate functional or component redundancy within these blocks (see Figure I.7).



A. FOR TWIN ENGINE AIRCRAFT, FULL CAPACITY MISSION



B. FOR TWIN ENGINE AIRCRAFT, SAFETY ONLY

FIGURE I.7. RELIABILITY LOGIC STRUCTURE FOR SYSTEM CONFIGURATION
(Illustrative Only)

4. Prepare matrix of configuration data elements vs. mission type (see Figure I.8).
5. Discuss with PM the range of values of interest to Army in sensitivity study. Tabulate results using form similar to Figure I.8.

Computer Programming Summary

A program has been developed by AVSCOM-LS to provide logic block diagrams directly from LSA/MEA data tapes. However this must be modified to fit specific mission under investigation.

Mission Type

Configuration Parameters		Maximum Capability	Reduced Capability	Safety
Subsystem 1	n 1/ X X'			
Subsystem 2	n X X'			
Subsystem 3	n X X'			
. . . .				
Subsystem N	n X X'			

1/ All terms are defined in Glossary, Appendix A.

FIGURE I.8. WORKSHEET FOR IDENTIFYING SYSTEM CONFIGURATION PARAMETERS

DETERMINATION OF COMPONENT LIFE CHARACTERISTIC PARAMETERS

Problem Description

In its operational life a component is subjected to various operational and environmental stresses which may, singly or in combination, degrade the ability of the component to perform until that ability falls below an acceptable threshold. At that time the component is said to have failed. The dominant stresses which must be considered include, e.g., operating overload, calendar time, operating time, operating miles, or rounds, and such environmental stresses as temperature and humidity. If one assumes that the system is properly used, the prevailing functional arguments for failure usually relate to the duration of the operational hazards. Failure of the component may occur in any of several modes, e.g., breaks or open circuits, excessive wear, jamming, etc.

The life characteristics of a component can be expressed in terms of the probability distribution for surviving each mode as a function of the dominant hazard. Usually, where wearout is a factor, two parameters will be required to define this distribution with sufficient accuracy, e.g., the mean time between failure (MTBF) and the probability of surviving half the MTBF, P(MTBF/2), for the i^{th} mode of failure. Where failures occur randomly, an estimate of the MTBF is sufficient.

At the design and development (D/D) stage, engineering estimates of component characteristics are documented, both in MEADS and in associated RAM documentation. These data, coupled with limited bench test results at the component/subsystem level will represent the best of current thinking, and when available they should be considered for updating the component life estimates obtained during the concept stage. The basic problem is to draw together the relevant D/D data, to assess its adequacy relative to the concept stage data, and to select the currently "best" information.

As indicated earlier, AMSEC provides for consideration of either one or two "stages" of hazard exposure within a given failure mode (see page 23).

Analysis Procedure

1. Draw together existing engineering documentation of component parameters showing failure parameters by mode of failure. Data sources include both the cognizant PM and contractor.

2. Enter this documentation in matrix form (see Figure I.9) for comparative presentation along with any existing data from concept stage (see Figure I.2).
3. Select "best" value for each parameter. Factors to be considered include:
   a. Extent of experience behind concept-stage estimates.
   b. Validity of concept stage data from generically similar subsystem; extent of similarities in design, use.
   c. Quality of data from D/D, e.g., depth of analysis, extent of tests, consistency of test results, similarity of test environment to use environment.
   d. If parameters are not available yet by mode, enter single value for all modes of failure.
4. Discuss with PM the range of values of interest to the Army in sensitivity studies. Tabulate results, using form similar to Figure I.9.

Computer Programming Studies

None required.

	Data Source											
	Concept Data			Engineering D/D Data			Other			Selected Nominal Values		
Parameter Values	Mode 1	Mode 2	Mode 3	Mode 1	Mode 2	Mode 3	Mode 1	Mode 2	Mode 3	Mode 1	Mode 2	Mode 3
Component 1												
Source priority												
Stage 1												
Par 1												
Par 2												
Stage 2												
Par 1												
Par 2												
Component 2												
.												
.												
.												
.												
.												
Etc.												

FIGURE I.9. WORKSHEET FOR SELECTION OF BEST ESTIMATES FOR COMPONENT LIFE PARAMETERS

DETERMINATION OF COMPONENT MAINTENANCE/MAINTAINABILITY CURVES AND PARAMETERS

Problem Description

The maintainability of a component describes the ability of the maintainer, of specified skill level, to detect and diagnose a failed component, and to take the appropriate replacement/repair actions. Design features such as accessibility and monitorability must be considered, as well as availability of skills, specialization of tools and equipment required, and training capability. Relevant maintainability parameters include $\underline{\alpha}$, $\underline{\beta}$, $\underline{\gamma_2}$, $\underline{\delta}$ and $\underline{h}$. The parameter $\gamma_{2k}(\tau)$, the distribution of removal/renewal time once action is initiated $\gamma_{1k}(t)$ is composed of several sub-elements, e.g., time to inspect, time to repair, and gap times while waiting for parts, for appropriate skills or for tools. Relevant maintenance parameters deal with the features of policy (e.g., $\underline{\gamma_1}$, $\underline{f_s}$) and the status of skills, tools and equipment provided.

At the design and development stage, the LSA documentation is becoming available, which provides preliminary quantitative estimates of the average value of γ_{2k}. Current documentation requirements do not call for estimation of the full distribution of γ_{2k}, or for estimates of $\underline{\alpha}$, $\underline{\beta}$, $\underline{\gamma_1}$ and $\underline{\delta}$. Consequently, a major source of parameter estimates during D/D will be structured engineering discussions, similar to those during the concept stage (see p. 28).

Analysis Procedure

1. Collect existing information bearing on the $\underline{M}$ parameters from both PM and contractors. This will usually provide improved estimates of the expected value of $\underline{\gamma_{2k}}$.
2. Conduct engineering discussions with PM-logistics and/or contractors to obtain improved estimates of γ_{2k} distribution, and estimates of mean values for α, β, γ_1, δ.
3. Bring forward data from concept stage (see Figure I.3).
4. Enter all data into new matrix (Figure I.10) for comparative presentation.
5. Select "best" value for each parameter. Factors to be considered include:
   a. Extent of experience behind concept stage estimates.

Data Source

Parameter Values	Concept Data	Engineering Data	Other Data	Selected Nominal Value
Component 1 $\alpha(\tau)$ 1/ $\beta(t)$ $\gamma_1(t)$ $\gamma_2(\tau)$ δ f_s h_0 h_1 h_2 h_3 $h_{4,m}$ f_s				
Component 2 . . . Etc.				

1/ All terms are defined in Glossary, Appendix A.

FIGURE I.10. WORKSHEET FOR DETERMINATION OF COMPONENT MAINTAINABILITY CURVES AND/OR PARAMETERS

b. Validity of concept stage data from generically similar subsystems (e.g., extent of similarity in design and use, and amount of data).

c. Quality of data from D/D, e.g., depth of analysis, extent of tests, consisting of test results.

d. Where no data are available, or quality is highly dubious, enter a priori values of $\underline{\alpha=1}$, $\underline{\beta=0}$, $\underline{\gamma_1=1}$, $\underline{\delta=1}$; estimate mean value of $\underline{\gamma_{2k}}$.

6. Discuss with PM the range of values of interest to the Army in sensitivity studies. Tabulate results using form similar to Figure I.10.

<u>Computer Programming Studies</u>

None required.

DETERMINATION OF LOGISTIC SUPPORT PARAMETERS

Problem Description

The logistic complex which supports a fleet of operating systems is comprised of the entire chain of functions from production and acquisition to shipping, storage/inventory, handling, inspection and preparing for use. These functions all have as their ultimate objective the supplying of necessary skills and components to keep the fleet in a required state of readiness. The figures of merit for the logistic system include:

a. The probability that the fleet support spares inventory will be sufficient to satisfy all demands over a specified period of time, and

b. The cost of the logistic system allocatable to the fleet under consideration. This logistic cost, is one component of the total cost of acquiring a component (i.e., acquisition cost = cost of production plus cost of delivery).

The top level parameters [2/] describing the logistic complex are:

a. The number of aircraft in the fleet to be supported (h)

b. The number of replacements for the k^{th} equipment which are on hand (W_k), and

c. The statistical protection level which is required (Q) for the fleet.

The three parameters are interdependent, so that if two are given, the third can be calculated through AMSEC. Normally the parameters which are required as input are h and Q, with AMSEC providing an estimate of the spares required for each component, in order to provide the specified level of fleet protection.

[2/] It should be noted that W, h, and Q are all derived variables dependent on still more basic underlying considerations. For example:

- h depends upon acquisition rate, delivery schedule, fleet size, deployment rate, de-commissioning rate, crash frequency, enemy vulnerability.
- Q depends upon replacement time, allowable downtime, mission criticality, feasible inventory size.
- W_k depends upon component failure characteristics, mission profile, plan for use, component utilization, delivery time.

At the D/D stage the values of h and Q should be much better definitized than at the concept stage, if only because the system configuration and capability is better known, its weaknesses more completely documented, and the mission/environment more specific. The principal sources of information, as at the concept stage, will be the cognizant PM and TRADOC.

Analysis Procedure

1. Carry forward results of discussions with TRADOC and with the cognizant PM at the concept stage to determine probable range of values of H and Q (see p.32).
2. Review these earlier findings with the cognizant PM and TRADOC to assess current validity. New factors to be considered include relevant system findings during D/D, changes in plans for acquisition, deployment and/or field use.
3. Update or modify as required. Use median value for point estimates; use entire range for sensitivity.
4. Enter findings in matrix from worksheet (refer to Figure I.4) for final review prior to entry into AMSEC.

Computer Programming Summary

None required.

DETERMINATION OF OPERATIONAL USE PARAMETERS

Problem Description

The operational use parameters describe the conditions of frequency and urgency under which the system will be deployed. Particular parameters for input to AMSEC include $\underline{\nu}$, $\underline{t}$, $\underline{\tau}$, $\underline{\rho}$, and R_C. Here it is assumed that "nominal" operating and environmental stresses will hold. If these stresses fall outside of the nominal operating range, the effect will be entered through changes in the life characteristics or maintainability parameters. AMSEC can accept inputs of $\underline{\nu}$, $\underline{t}$, $\underline{\tau}$, $\underline{\rho}$, and R_C on the basis of average values, and deal with the entire span of system use over which these averages are assumed to hold; or it can accept different missions, different component utilization, and different allowed times between missions for investigation of alternative scenarios.

Usually $\underline{\nu}$ is considered as a running variable and component/system degradation in RMAC is estimated in terms of age measured against $\underline{\nu}$. However each variable can be considered alternatively as being fixed, or as a variable.

At the D/D stage the operational use parameters should be more definitized than at the concept stage, because the system capability is better known and its range of possible field uses have been more thoroughly explored. The principle sources of information, as at the concept stage, will be the cognizant PM and TRADOC.

Analysis Procedure

1. Carry forward results of discussions with TRADOC and with the cognizant PM at the concept stage to document the then-current plans for use.
2. Review these earlier findings with the cognizant PM and with TRADOC to assess current validity. New factors to be considered include relevant system findings during D/D, changes in deployment, newly determined environmental/logistic constraints.
3. Update or modify as required.
4. Enter selected values in tabular form (see Table I.11).

Computer Programming Summary

None required.

TABLE I.11. WORKSHEET FOR DETERMINATION OF OPERATIONAL USE PARAMETERS

	Data Source			
Parameters	Concept Data	Engineering Data	Other Data	Selected Nominal Value
ν				
t				
τ				
R_C				
ρ_1				
ρ_2				
.				
.				
.				
ρ_N				

DETERMINATION OF SUPPORT COST PARAMETERS

Problem Description

The cost of system support allocatable to a component is composed of four basic factors:

a. The cost of material, that is, the end cost of the component to the user, including costs of acquisition; delivery, storage and interim servicing; testing, and preparation for use.

b. The cost of labor ($/hr) involved in actual removal/repair activities. This includes routine handling.

c. The cost of non-routine handling for, e.g., a system that failed in use and had to be air-lifted back to depot for maintenance.

d. The cost of failure over and above the cost of replacing the failed component. This can be thought of as the cost of unreliability, plus the cost of unavailability, and may include, for example, crash damage, loss of life, or loss of a mission.

Each cost factor can be sub-categorized in terms of the particular mode of failure/removal to which the cost is applicable. The problem here is to formulate a cost profile for each component, based on these four factors, from the best available sources of information. At the concept stage, the availability of much of the relevant data will depend upon whether the component is "off-the-shelf" or is a new design.

Analysis Procedure

1. For each subsystem/component under investigation, determine if it is a new design or is "off-the-shelf".

2. (a) If it is "off-the-shelf", investigate availability of existing cost records through cognizant PM or other source. If available follow procedures for appropriate stage of development.

(b) If not "off-the-shelf" or if cost data are not available, proceed to Step 3 below.

3. Obtain existing documentation on component cost parameters and/or estimates from the cognizant PM, from Procurement, and from contractor sources.
4. Conduct discussions with PM cost analysts and Procurement specialists. These discussions should be structured, first to bracket the parameter value in question, then to narrow the bracket as much as possible. Factors to be considered include changes in consumer price index and in labor rates; changes in design modularity/accessibility for components; availability of special tools/equipment; delivery method to be used, and impact of component failure on safety, mission success, by mode of failure.
5. Prepare matrix of sources vs. cost data and enter estimates (see Figure I.12).
6. Prepare estimates of priority to be assigned to different sources, and enter on worksheet.
7. Enter selected value of each parameter. This will normally be the value corresponding to the highest priority source. If a different value is selected, enter reason for such selection as an exhibit.

TABLE I.12 WORKSHEET FOR DETERMINATION OF COST PARAMETERS

Cost Parameter	Procurement	Data Source AVS PM	Other	Selected Nominal Value
Source priority				
Component 1 Labor cost per man hour PM removal HT failure CM, Mode 1 2 : m				
Material Cost Service PM removal H/T failure CM, Mode 1 2 3 : m				
Component 2 Etc.				

CHAPTER 3

INPUT PARAMETERS--FIELD TESTING STAGE

INTRODUCTION

The field testing phase of a system development represents, in a sense, a final (or near final) step in the development process. The design configuration at this point is essentially constrained to prevent major modifications. A maintenance concept has been implemented which, although it may change in some particulars as the system becomes operational, at least recognizes the fact that such major factors as component design, accessibility, maintainer skills, and the nature of diagnostic and other special equipment, have also become less subject to significant change.

The field testing itself has as a major objective the generation of data which permits a more objective estimation of system performance capability and of RAM parameters. Consequently it is of critical importance that the field tests be designed for the most efficient production of the necessary data base.

The Reliability, Availability, Maintainability, Logistics (RAM/LOG) Data System [3] has been designed and implemented for the collection and processing of development/test/operational data. RAM/LOG is specifically tailored to developing the data necessary for RAM evaluation and for management control through AMSEC. If the data collection during field testing is based on these particular

[3] TR 9-9, Structure of Integrated RAM Data Base for UTTAS, 9 October 1975, Prepared for U.S. Army Aviation Systems Command.

RAM/LOG forms and procedures, estimates of the relevant AMSEC parameters will be routinely provided by the algorithms associated with the data system. If a less comprehensive data system is used during the test phase, special processing procedures may be required, and some of the RAM-related parameters may not be documented at all.

The procedures for parameter estimation at the field test stage differ from those at the concept and design stages in that actual in-use behavior has been documented. For the first time in the development process, it is possible to draw from these documented observations direct estimates of component failure parameters and component repair/maintenance times. However the data may be of limited value if the number of such observations is too limited. Consequently the problem facing the analyst at the test stage is:

1. The development of parameter estimates from test observations, and
2. The decision as to whether to use these estimates to supplement the earlier estimates, to accept them in conjunction with the earlier estimates, or to disregard them.

The following pages describe the analysis process for each element of input data.

DETERMINATION OF SYSTEM CONFIGURATION PARAMETERS

Problem Description

As field testing begins on a system, the configuration for design and support is essentially fixed and should be fully documented in the contractors work breakdown structure and the MEA documents. In addition the various missions anticipated for the system in operational use should be defined and the overall plan for use and the support plan should be laid out. These latter parameters can be changed depending on the findings during the test phase; the configuration parameters can also be varied through the engineering-change process but the range of feasible variation is more limited.

The objective at this stage is to document the final system values of $\underline{N}$, $\underline{n_k}$, $\underline{X_k}$, and $\underline{X'_k}$ and the interconnection logic for each of the various mission types under consideration, and to determine those parameters which may be subject to review through the ECP route.

Analysis Procedure

1. Obtain updated design logic diagrams from the cognizant PM; obtain updated work breakdown structure from contractor MEADS.
2. Obtain updated mission concepts from PM or TRADOC, and designate components required for different specified missions.
3. Lay out subsystem R/A block diagrams for different missions. Group subsystems into major functional groups, each of which is required for the specified mission, and thus are in series logically. Indicate sub-functional or component redundancy within these major groups (see Figure I.7 for illustration).
4. Prepare matrix of configuration data elements vs. mission type (see Figure I.8 for illustration).

5. Discuss with PM the major configurational parameters; tabulate results using form similar to Figure I.8.

Computer Programming Summary

A program has been developed to provide logic block diagrams from LSA data tapes. However, this must be modified to fit the specific mission(s) under investigation.

DETERMINATION OF COMPONENT LIFE CHARACTERISTIC PARAMETERS

Problem Description

During the system test phase, each component will be subjected to the operational and environmental stresses of an in-use environment. As a result, failures may be expected, with follow-on repair or renewal before the system can continue in fully effective operation. In principle, if testing continues long enough, each component will experience a time-sequence of use-removal-repair/replacement-continued use. Each removal/renewal will have a specified reason, the reasons so specified including both modes of actual failure and administrative or other causes. If the removals are documented by cause, and the intervening operation of the system is documented by type and duration of missions, then it follows that parameter estimates can be derived describing the distribution of time-to-removal, (or miles, rounds, etc.) by component and by reason for renewal.

The degree of usefulness of these estimates will depend on two major test characteristics:

1. The representativeness of the test environment(s) to the environments surrounding later operation of the system, and
2. The extent that coverage and duration of the test(s) leads to sufficient precision and accuracy of parameter estimates for insertion into AMSEC in determining RMAC for the later operational phase.

If both conditions hold, the test-derived estimates may be used to supplant the estimates obtained during earlier stages. If they do not hold, or hold partially, then a decision must be made as to whether to retain the earlier estimates, modify them or supplant them.

Analysis Procedure

The following procedures represent steps taken by the AMSEC data transducer, to convert empirical data on component removals by reason, or failure mode, to the corresponding estimates of life characteristic parameters for entry into the AMSEC RMAC Model. These procedures comprise a combination of manual and computer steps.

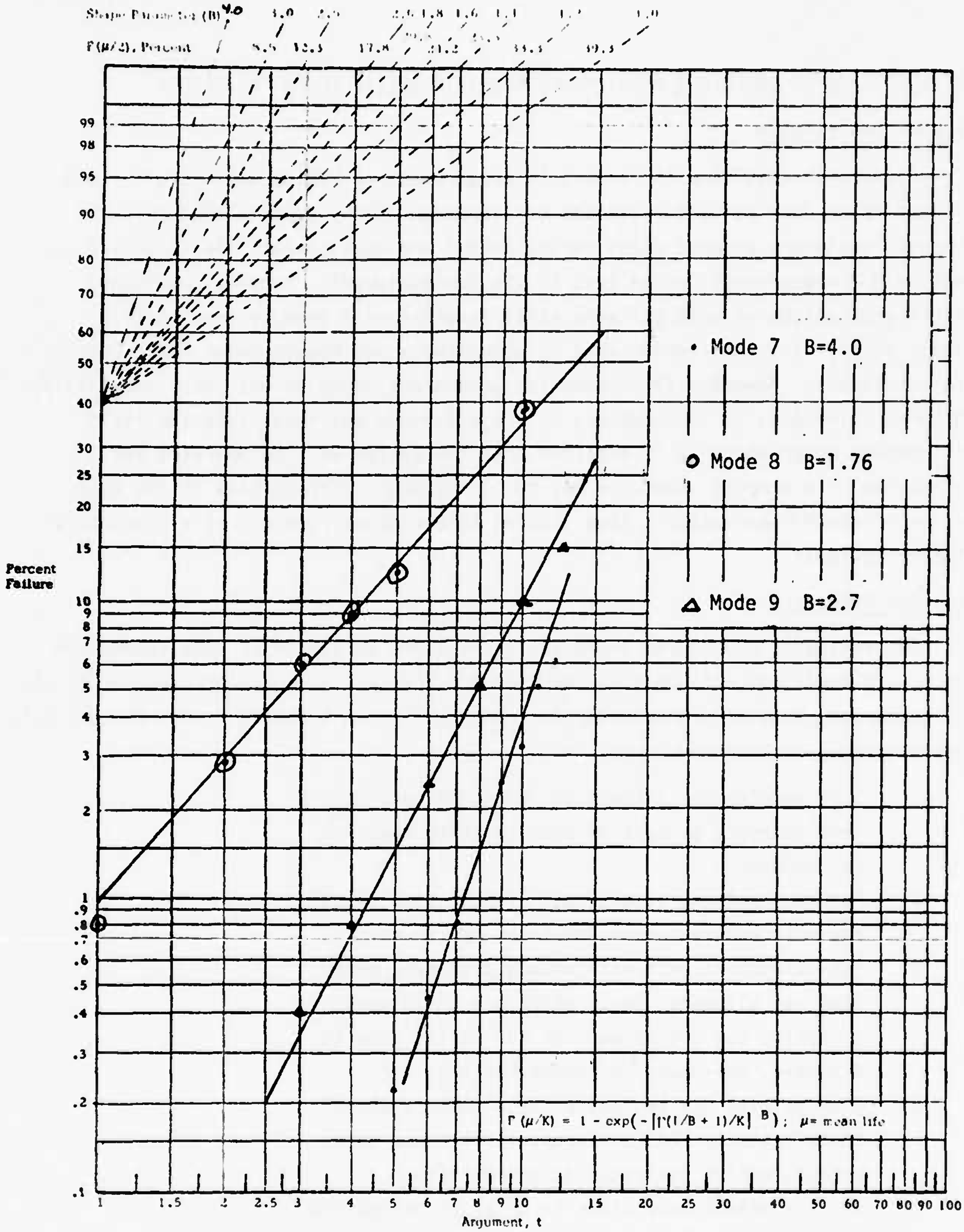
For each component being tested:

1. Determine dominant failure argument for end subsystem/component--e.g., time, flight hours, rounds.
2. Determine time to removal by cause, including prior operating time, if any.
3. Create histogram with time intervals sufficiently small to depict removal frequency curve
4. Creating say $\underline{\nu}$ intervals to cover the span of test time, record n_{ij}, the number of renewals for j^{th} cause in ith interval $i=1,\ldots,\nu$ and n_i the number of renewal for all causes in the interval.
5. Insert the n_{ij}'s and n_i's in AMSEC computer algorithm to determine estimates of survival probability by cause, viz., $\hat{R}_j(it)$, $i=1,\ldots\nu$
6. Plot $\hat{R}_j(it)$'s on Weibull probability paper[4/] other suitable plotting paper to determine failure distribution parameters for insertion into AMSEC. (See Figure I.13 for illustrative plot.)

Computer Programming Summary

Step 5 has been automated, to separate a totality of empirical observations of renewal into estimates of renewal distributions by reason for renewal. The mathematics underlying this algorithm are presented in Appendix B.

[4/] Weibull probability paper, obtainable from most engineering supply stores, is designed so that any distribution having a Weibull form $1-F(t) = e^{-A\,t^B}$ will lie in a straight line. If plots on Weibull are non-linear $\{R_j(it), (it)\}$ point pairs can be used to establish linear segment curves (probability) for direct insertion into AMSEC.



WEIBULL PROBABILITY PAPER

$F(t) = 1 - \exp(-At^B)$

FIGURE I.13. TYPICAL WEIBULL PLOT OF REMOVAL DATA BY MODE FOR ENGINE

DETERMINATION OF COMPONENT MAINTENANCE/MAINTAINABILITY (M/M) PARAMETERS

Problem Description

Field test results with respect to measurement of M/M parameters will tend to confirm or deny earlier estimates derived from LSA's, special studies and proposed equipment support plans during design and development. An important aspect in M/M measurement during test is the human element. Properly motivated maintenance personnel with suitable skill level(s) will produce results (e.g., repair times, etc.) reflecting what is potentially achievable under field operating conditions. However, in considering parameters whose values rest importantly on human attitudes, it is necessary to project those attitudes into the field environment under which it is expected that the system will be operated and maintained. To proceed otherwise may be to introduce serious bias in the estimating of the M/M parameters, thus leading to erroneous forecast of system operational readiness.

Analysis Procedure

The following procedures represent steps taken by the AMSEC data transducer to convert empirical data on field maintenance actions, as documented either by the i^{th} component, depending on whether the component is in a failed or non-failed state when maintenance commences.

1. Sort maintenance actions by component, and within that category by type of problem which required maintenance.
2. For each action, list total calendar time required for maintenance action and total man-hours.
3. Sub-categorize each maintenance time/man-hours into its elemental parts which are of interest in analysis, e.g., time waiting for parts, time to diagnose, man-hours to remove/replace, etc.
4. Discuss with M/M engineers the extent to which these estimates would represent field-use capability; modify estimates as appropriate.
5. Arrange maintenance times in order of increasing duration; compute fraction of observations reflecting maintenance time less than a prescribed time

for use in determining $\underline{\alpha(\tau)}$ and $\gamma_2(\tau)$, the probabilities respectively that cm and pm will be accomplished in τ or less time.

6. Determine operating times between preventive maintenance actions. Sort actions requiring component renewal from those in the nature of service, e.g., lubrication.
7. Rank-order operating times between PMs resulting in component renewal, e.g., remove/replace.
8. Compute fraction of times less than prescribed times for estimation of $\gamma_1(t)$, the probability of renewal of a non-failed component which has been operating for time t. [5/]
9. Determine frequency of service type actions per operating hour.

Computer Programming Summary

The computational process for estimating distributions from a series of observations of α_1, γ_1, γ_2, f_s or h is the equivalent of that for calculating the distribution of survival probability (p. 62). If the distribution is assumed to be Weibull, the appropriate parameters can be determined by the use of Weibull graph paper, as shown on page 63. The process is being automated for application on an ongoing program by AVSCOM, and will be available for use.

[5/] Note: The maintenance plan for a component may call for a renewal at some prescribed operating time if failure of the component does not intervene. To the extent that field testing follows the maintenance plan directive $\gamma_1(t)$ will behave as a step function, i.e., if $t < t_0$, $_1(t) = 0$; at $t = t_0$ $\gamma_1(t) = 1$. It may not be necessary to record actual times between PM renewals but rather, through documentation, to verify that the prescribed time (t_0) for PM renewal is being observed.

DETERMINATION OF LOGISTIC SUPPORT PARAMETERS

Problem Description

The logistic complex which supports a fleet of operating systems is comprised of the entire chain of functions covering support material and personnel associated with production, acquisition, shipping, storage/inventory, handling, inspection and preparation of system for use. These functions all have as their ultimate objective the supply of personnel and component inventories sufficient to keep the fleet in a required state of preparedness. The figures of merit for the logistic system are:

a. Fleet/organizational readiness:
   What fraction of systems are ready to accomplish defined missions of interest?
   What fraction of systems are not ready to accomplish defined missions of interest because of:
   1. Support material deficiencies, e.g., insufficient spare parts
   2. Support personnel or equipment deficiencies, e.g., lack of necessary skill level to maintain necessary component(s).

b. Fleet support cost with respect to:
   1. Personnel direct and indirect man-hours for support.
   2. Material acquisition.

The top level parameters [6] describing and influencing the logistic complex are:

a. The number of systems in the fleet to be supported ($\underline{h}$).
b. The number of missions (ν) per system.
c. The duration (t) of mission.

---

[6] It should be noted that these parameters are, in general, derived variables dependent on still more basic underlying considerations: For example:

- h depends upon acquisition rate, delivery schedule, fleet size, deployment rate, decommissioning rate, crash frequency, enemy vulnerability.
- Q depends upon replacement time, allowable downtime, mission criticality, feasible inventory size.
- W_k depends upon component failure characteristics, mission profile, plan for use, component utilization, delivery time.

d. Lead times for spare parts requisition ($\underline{T}$).

e. The number of replacements for the k^{th} equipment ($\underline{W_k}$).

f. The protection levels for each type component part ($\underline{Q}$).

The values of W, h, and Q usually refer to the operational use environment. H and Q, as the independent parameters, were defined roughly during earlier stages. During the test stage some refinement in these earlier estimates may be made, based on test findings, and it is important to review the question with PM logistics and TRADOC.

Analysis Procedure

1. Carry forward results of discussions with TRADOC and with PM at the concept and D/D stages to determine probable range of values of h and Q

2. Review these earlier findings with the cognizant PM and TRADOC to assess current validity. New factors to be considered include relevant system findings during test, changes in plans for acquisition, deployment and/or field use.

3. Update or modify as required. Use median value for point estimates; use entire range for sensitivity.

4. Enter findings in matrix form worksheet (refer to Figure I.10) for final review prior to entry into AMSEC.

Computer Programming Summary

None required.

DETERMINATION OF OPERATIONAL USE PARAMETERS

Problem Description

The operational use parameters describe the conditions of frequency and urgency under which the system will be deployed. Particular parameters for input to AMSEC include $\underline{\nu}$, $\underline{t}$, $\underline{\tau}$, $\underline{\rho}$, and R_C. Here it is assumed that "nominal" operating and environmental stresses will hold. If these stresses fall outside of the nominal operating range, the effect will be entered through changes in the life characteristics or maintainability parameters. AMSEC can accept inputs of $\underline{\nu}$, $\underline{t}$, $\underline{\tau}$, $\underline{\rho}$, and R_C on the basis of average values, and deal with the entire span of system use over which these averages are assumed to hold; or it can accept different missions, different component utilization, and different allowed times between missions for investigation of alternative scenarios.

Usually ν is considered as a running variable, and component/system degradation in RMAC is estimated in terms of age measured against $\underline{\nu}$. However each variable can be considered alternatively as being fixed, or as a variable.

Preliminary values of the operational use parameters will have been defined at earlier stages of development; however, during the field testing stage certain modifications and updates in these parameters may be expected, since the capability of the system and mission interests may have changed. It is important to review these earlier parameter definitions with the primary sources of such information--the cognizant PM and TRADOC--and make the necessary updates.

Analysis Procedure

1. Carry forward results of discussions with TRADOC and with the cognizant PM at the concept stage to document the then-current plans for use.
2. Review these earlier findings with the cognizant PM and with TRADOC to assess current validity. New factors to be considered include relevant system findings during D/D, changes in deployment, newly determined environmental/logistic constraints.
3. Update or modify as required.
4. Enter selected values in tabular form (see Table I.11).

Computer Programming Summary

None required.

DETERMINATION OF SUPPORT COST PARAMETERS

Problem Description

The cost of system support allocatable to a component is composed of four basic factors:

a. The cost of material, that is, the end cost of the component to the user, including costs of acquisition; delivery, storage and interim servicing; testing, and preparation for use.

b. The cost of labor ($/hr) involved in actual removal/repair activities. This includes routine handling.

c. The cost of non-routine handling for, e.g., a system that failed in use and had to be air-lifted back to depot for maintenance.

d. The cost of failure over and above the cost of replacing the failed component. This can be thought of as the cost of unreliability, plus the cost of unavailability, and may include, for example, crash damage, loss of life, or loss of a mission.

Each cost factor can be sub-categorized in terms of the particular mode of failure/removal to which the cost is applicable. The problem here is to formulate a cost profile for each component, based on these four factors, from the best available sources of information. At the concept stage, the availability of much of the relevant data will depend upon whether the component is "off-the-shelf" or is a new design.

Analysis Procedure

1. For each subsystem/component under investigation, determine if it is a new design or is "off-the-shelf".

2. (a) If it is "off-the-shelf", investigate availability of existing cost records through cognizant PM or other source. If available follow procedures for appropriate stage of development.

   (b) If not "off-the-shelf" or if cost data are not available, proceed to Step 3 below.

equipment, labor skills required for maintenance, as determined during tests; changes in mission use and hence on component failure cost; changes in failure mode distribution, and thus on expected failure cost; changes in price indices.

3. Enter revised parameter estimates in matrix form (e.g., Table I.12 or equivalent) for later entry into AMSEC.

Computer Programming Summary

None required.

CHAPTER 4
INPUT PARAMETERS--OPERATIONAL USE STAGE

INTRODUCTION

Operational use represents the final stage of the system life cycle. The design has been established, except for a limited number of engineering changes which may be considered. A maintenance program is in being which, although it may be changed in some details to improve cost-effectiveness, recognizes that such major factors as component design, special equipment, available skills, etc. have been fixed. Tests have been completed so that as operational use begins, the best possible data base is available.

On the basis of this backlog of experience with system characteristics, the Army must now decide how it is going to use the system in the field, which design changes make sense, and what maintenance plan is most cost-effective. This will be a learning process, starting with projected parameter values at the beginning of operational use, and modifying these values as experience in the actual use-environment is gained. Consequently it is of critical importance that the use experience be carefully documented to support this learning/decision process.

The Reliability, Availability, Maintainability, Logistics (RAM/LOG) Data System [1/] was designed for the collection and processing of development/test/operational data. Specifically, it will develop the data necessary as input for RAM evaluation and for management control through AMSEC. If the data collection during operational use is based on the RAM/LOG forms

[1/] TR 9-9, Structure of Integrated RAM Data Base for UTTAS, 9 October 1975.

and procedures, estimates of the relevant AMSEC parameters will be routinely provided by the algorithms associated with the data system. If a less comprehensive data system is used during system operation, special processing procedures may be required, and some of the RAM-related parameters may not be documented at all.

The procedures for parameter estimation at the operational use stage resemble those at the test phase, and in a sense represent simply an extension of the "test" experience into a more realistic environment. As in the test phase, parameter estimates can now be drawn from actual documented observations, rather than from engineering estimates or generic experience. Also, as in the test phase, the data may be of limited value if the number of such observations is too limited. Consequently the problem facing the analyst at the operational use stage is two-fold:

1. The development of parameter estimates from actual field-use observations, and
2. The decision as to whether to use these estimates to supplement the earlier estimates, to accept them in conjunction with the earlier estimates, or to disregard them.

The following pages describe the analysis process for each element of input data.

DETERMINATION OF SYSTEM CONFIGURATION PARAMETERS

Problem Description

Starting the operational phase, the system design configuration is essentially fixed. It has been fully documented, first in the contractors work breakdown structure and the LSA documents, and later in changes introduced during development or as a result of testing. In addition the various missions anticipated for the system in operational use have been defined and the overall plan for use and the support plan have been laid out. These latter parameters are based on the latest findings during the test phase and can be varied as operating experience indicates. The configuration parameters can also be varied through the engineering-change process but the range of feasible variation is limited.

The objective at this stage is to document the final system values of $\underline{N}$, $\underline{n_k}$, $\underline{X_k}$, and $\underline{X'_k}$ and the interconnection logic for each of the various mission types under consideration, and to determine those parameters which may be subject to review through the ECP route.

Analysis Procedure

1. Obtain updated design logic diagrams from PM; obtain updated work-breakdown structure from final contractor LSA documentation.
2. Obtain updated mission concepts from PM or TRADOC, and designate components required for different specified missions.
3. Lay out subsystem R/A block diagrams for different missions. Group subsystems into major functional groups, each of which is required for the specified mission, and thus are in series logically. Indicate sub-functional or component redundancy within these major groups (see Figure I.7 for illustration).
4. Prepare matrix of configuration data elements vs. mission type (see Figure I.8 for illustration).
5. Discuss with PM the major configurational parameter candidates for ECPs; tabulate results using form similar to Figure I.8.

Computer Programming Summary

A program has been developed to provide logic block diagrams directly from LSA data tapes. However, this must be modified to fit the specific mission under investigation.

DETERMINATION OF COMPONENT LIFE-CHARACTERISTIC PARAMETERS

Problem Description

During the operational use phase, each component will be subjected to the operational and environmental stresses of the actual in-use environment. Failures will be expected as a result of those stresses, repairs or renewal will take place, and system operation will continue. In principle, over the full operational life of the system, each component will experience a time-sequence of use-removal-repair/replacement-continued use. Each removal will be characterized by a specified reason for renewal, the reasons so specified including both modes of actual failure and administrative or other reasons. If the removals are documented by cause, and the intervening operation of the system is documented by type and duration of missions, then parameter estimates can be derived describing the distribution of time-to-removal, (or miles, rounds, etc.) by component and by reason for renewal.

Analysis Procedure

The following procedures represent steps taken by the AMSEC data transducer, to convert empirical data on component removals to corresponding estimates of life characteristics for entry into the AMSEC RMAC model.

For each component being tested:

1. Determine dominant failure argument for end subsystem/component--e.g., time, flight hours, rounds.
2. Determine time to removal by cause.
3. Create histogram with time intervals sufficiently small to depict removal frequency curve.
4. Creating say ν intervals within the expected component life cycle, record n_{ij} the number of renewals for j^{th} cause in i^{th} interval $i=1,\ldots\nu$. Record n_i, the number of renewals for all causes in the interval.
5. Insert the n_{ij}'s and n_i's in AMSEC computer algorithm to determine estimates of survival probability by cause, viz., $\hat{R}_{ij}(i\ t)$, $i = 1, 2\ldots\nu$.

6. Plot $\hat{R}_j(it)$'s on Weibull probability paper or other suitable plotting paper to determine failure distribution parameters for insertion into AMSEC. [7/]

Computer Programming Summary

Step 5 has been automated, to separate a totality of empirical observations of renewal into estimates of renewal distributions by reason for renewal. The mathematics underlying this algorithm are presented in Appendix B.

7/ If plots on Weibull are non-linear $\{R_j(it), it\}$ point pairs can be used to establish linear segment curves (probability) for direct insertion into AMSEC.

DETERMINATION OF COMPONENT MAINTENANCE/MAINTAINABILITY PARAMETERS

Problem Description

As operational use begins, the engineering estimates of the M/M parameters will have been defined either through formal LSA reporting, through special developmental studies, through the AMSEC dialogue described in Chapter 2, or through test results. During field use, component removals, replacements, adjustments and repairs will take place under actual operational conditions. As system use continues, more accurate estimates of the M/M parameters and their distributions can be obtained, which can then be used in AMSEC for system evaluation and planning. These estimates of course may not hold under different operating conditions depending on the human equation as reflected in maintenance personnel motivation and incentive to perform.

Analysis Procedure

The following procedures represent steps taken by the AMSEC data transducer to convert empirical data on field maintenance actions, as documented either by RAM/LOG or by other systems, into estimates for the values of maintenance time for the i^{th} component, depending on whether the component is in a failed or non-failed state when maintenance commences.

1. Sort maintenance actions by component, and within that category by type of problem which required maintenance.
2. For each action, list total calendar time required for maintenance action and total man-hours.
3. Sub-categorize each maintenance time/man-hours into its elemental parts which are of interest in analysis, e.g., time waiting for parts, time to diagnose, man-hours to remove/replace, etc.
4. Arrange maintenance times in order of increasing duration; compute fraction of observations reflecting maintenance time less than a prescribed time for use in determining $\underline{\alpha(\tau)}$ and $\underline{\gamma_2(\tau)}$, the probabilities respectively that CM and PM will be accomplished in τ or less time.

5. Determine operating times between preventive maintenance actions. Sort actions requiring component renewal from those in the nature of service, e.g., lubrication.
6. Rank-order operating times between PMs resulting in component renewal, e.g., remove/replace.
7. Compute fraction of times less than prescribed times for estimation of $\underline{\gamma_1}(t)$, the probability of renewal of a non-failed component which has been operating for time t. 8/
8. Determine frequency of service type actions per operating hour.

Computer Programming Summary

All of these steps have been programmed for computer use, to estimate the distributions for $\underline{\alpha}$, $\underline{\gamma}$, $\underline{\gamma_2}$ and the f_s and $\underline{h}$ values, from the maintenance data forms of RAM/LOG. This program was documented in TR 9-12, dated 16 January 1976, and the program itself was transferred to AVSCOM-PA.

8/ Note: The maintenance plan for a component may call for a renewal at some prescribed operating time if failure of the component does not intervene. To the extent that field testing follows the maintenance plan directive $\gamma_1(t)$ will behave as a step function, i.e., if $t < t_0$, $\gamma_1(t) = 0$; at $t = t_0$ $\gamma_1(t) = 1$. It may not be necessary to record actual times between PM renewals but rather through documentation to verify that the prescribed time (t_0) for PM renewal is being observed.

DETERMINATION OF LOGISTIC SUPPORT PARAMETERS

Problem Description

The logistic complex which supports a fleet of operating systems is comprised of the entire chain of functions covering support material and personnel associated with production, acquisition, shipping, storage/inventory, handling, inspection and preparation of system for use. These functions all have as their ultimate objective the supply of personnel and component inventories sufficient to keep the fleet in a required state of preparedness. The figures of merit for the logistic system are:

a. Fleet/organizational readiness:
   What fraction of systems are ready to accomplish defined missions of interest?
   What fraction of systems are not ready to accomplish defined missions of interest because of:
   1. Support material deficiencies, e.g., insufficient spare parts
   2. Support personnel or equipment deficiencies, e.g., lack of necessary skill level to maintain necessary component(s).

b. Fleet support cost with respect to:
   1. Personnel direct and indirect man-hours for support.
   2. Material acquisition.

The top level parameters [9] describing and influencing the logistic complex are:

a. The number of systems in the fleet to be supported (h).
b. The number of missions (ν) per system.
c. The duration (t) of mission.

---

[9] It should be noted that these parameters are, in general, derived variables dependent on still more basic underlying considerations: For example:

- h depends upon acquisition rate, delivery schedule, fleet size, deployment rate, decommissioning rate, crash frequency, enemy vulnerability.
- Q depends upon replacement time, allowable downtime, mission criticality, feasible inventory size.
- W_k depends upon component failure characteristics, mission profile, plan for use, component utilization, delivery time.

d. Lead times for spare parts requisition (T).

e. The number of replacements for the k^{th} equipment $\underline{W_k}$.

f. The protection levels for each type component part (Q).

The values of W, h, and Q usually refer to the operational use environment. H and Q, as the independent parameters, were defined roughly during earlier stages. During the operational stage some refinement in these earlier estimates may be made, based on actual use findings, and it it important to review the question with PM logistics and with the field commander.

Analysis Procedure

1. Carry forward results of discussions with TRADOC and with PM at the concept and D/D stages to determine probable range of values of H and Q.
2. Review these earlier findings with the cognizant PM and with field commander to assess current validity. New factors to be considered include relevant system findings during field use, changes in plans for acquisition, deployment, and tactical use.
3. Update or modify as required. Use median value for point estimates; use entire range for sensitivity.
4. Enter findings in matrix form worksheet (refer to Figure I.10) for final review prior to entry into AMSEC.

Computer Programming Summary

None required.

DETERMINATION OF OPERATIONAL USE PARAMETERS

Problem Description

The operational use parameters describe the conditions of frequency and urgency under which the system will be deployed. Particular parameters for input to AMSEC include $\underline{\nu}$, $\underline{t}$, $\underline{\tau}$, $\underline{\rho}$, and R_C. Here it is assumed that "nominal" operating and environmental stresses will hold. If these stresses fall outside of the nominal operating range, the effect will be entered through changes in the life characteristics or maintainability parameters. AMSEC can accept inputs of $\underline{\nu}$, $\underline{t}$, $\underline{\tau}$, $\underline{\rho}$, and R_C on the basis of average values, and deal with the entire span of system use over which these averages are assumed to hold; or it can accept different missions, different component utilization, and different allowed times between missions for investigation of alternative scenarios.

Usually ν is considered as a running variable and component/system degradation in RMAC is estimated in terms of age measured against ν. However each variable can be considered alternatively as being fixed, or as a variable.

Preliminary values of the operational use parameters will have been defined at earlier stages of development; however, during the operational use stage certain modifications and updates in these parameters are to be expected, since the capability of the system is now completely documented, mission interests are better defined, and environments are now known or more fully understood. It is important to review these earlier parameter definitions with the primary sources of such information--the cognizant PM, TRADOC, field commander--and make necessary updates.

Analysis Procedure

1. Carry forward results of discussions with TRADOC and with the cognizant PM at the testing stage to document the then-current plans-for-use.
2. Review these earlier findings with the cognizant PM, with TRADOC and with the operational commander, to assess current validity. New factors to be considered include relevant system findings during test, changes in deployment and tactics.

3. Update or modify as required.
4. Enter selected values in tabular form (see Table I.11).

Computer Programming Summary

None required.

DETERMINATION OF SUPPORT COST PARAMETERS

Problem Description

The cost of system support allocatable to a component is composed of four basic factors:

a. The cost of material, that is, the end cost of the component to the user, including costs of acquisition; delivery, storage and interim servicing; testing, and preparation for use.

b. The cost of labor ($/hr) involved in actual removal/repair activities. This includes routine handling.

c. The cost of non-routine handling for, e.g., a system that failed in use and had to be air-lifted back to depot for maintenance.

d. The cost of failure over and above the cost of replacing the failed component. This can be thought of as the cost of unreliability, plus the cost of unavailability, and may include, for example, crash damage, loss of life, or loss of a mission.

Each cost factor can be sub-categorized in terms of the particular mode of failure/removal to which the cost is applicable. The problem here is to formulate a cost profile for each component, based on these four factors, from the best available sources of information. At the concept stage, the availability of much of the relevant data will depend upon whether the component is "off-the-shelf" or is a new design.

Analysis Procedure

1. For each subsystem/component under investigation, determine if it is a new design or is "off-the-shelf".
2. (a) If it is "off-the-shelf", investigate availability of existing cost records through cognizant PM or other source. If available follow procedures for appropriate stage of development.

   (b) If not "off-the-shelf" or if cost data are not available, proceed to Step 3 below.

anticipated through ECPs; changes in special tools, equipment, labor skills required for maintenance as determined during tests; changes in mission use tactics and hence on component failure cost; changes in failure mode distribution, and thus on expected failure cost; changes in price indices.

3. Enter revised parameter estimates in matrix form (e.g., Table I.12 or equivalent) for later entry into AMSEC.

Computer Programming Analysis

None required.

SECTION II
USE OF RMAC EVALUATION MODEL
INTRODUCTION

Once input parameter values have been established (see Section I), operation of the AMSEC RMAC Model can begin. Inputs will vary in degree of definition and precision as the development program proceeds. However, their use in the RMAC evaluation process follows the same steps in the Concept Stage, the Design and Development Stage, the Test Stage or the Operational Use Stage. Consequently the organization of Section II is not broken down by Chapters for different stages of development, but rather is a single Chapter describing the implementation of the model in detail.

The input and output formats are described, along with the procedures for entering the data into the computer. The analytic formulation of AMSEC, and the documentation of the computer program is discussed in Appendix C. The cards for the program have been provided to AVSCOM-PA under separate cover.

A full illustrative printout from the model, showing the output values for system and component RMAC and spares, and the expected change of these parameters with system use is provided in Appendix D. Specialized analysis outputs are provided as accompaniment to the text in Section III.

CHAPTER 1
RMAC MODEL
CONCEPT, DEVELOPMENT, TEST AND USE STAGES

INTRODUCTION

The major differences in using AMSEC in the various stages of system development are:

a. Differences in output due to changes in system definition and design characteristics.

b. Differences in the precision and accuracy with which input data are established, and

c. Differences in the specific AMSEC applications which are of concern to management.

The actual operation of the RMAC model--i.e., the calculation, from a given set of input values, of system/component RMAC and spares, broken down by mode of failure/renewal--is essentially the same at all stages. The steps involved are the following:

1. Collection and organization of input parameter estimates as developed in Section I, for each component
2. Entry of appropriate parameter estimates onto input format for keypunch
3. Keypunch of input data onto program cards
4. Specification of form(s) of outputs desired
5. Entry of all data cards into computer and operation of AMSEC program to derive specified outputs and printout on appropriate output formats.

The following Chapter describes the single-step use of the RMAC model in terms of these basic steps, provides illustrations in each case, and displays a sample output for a simple system configuration. Such a single-run estimate of RMAC and spares (RMACS) histories is the basic model operation; it provides a complete evaluation from a set of single-value inputs for each parameter specified. For more complex management decisions, multiple-run evaluations are required; these are described in Section III.

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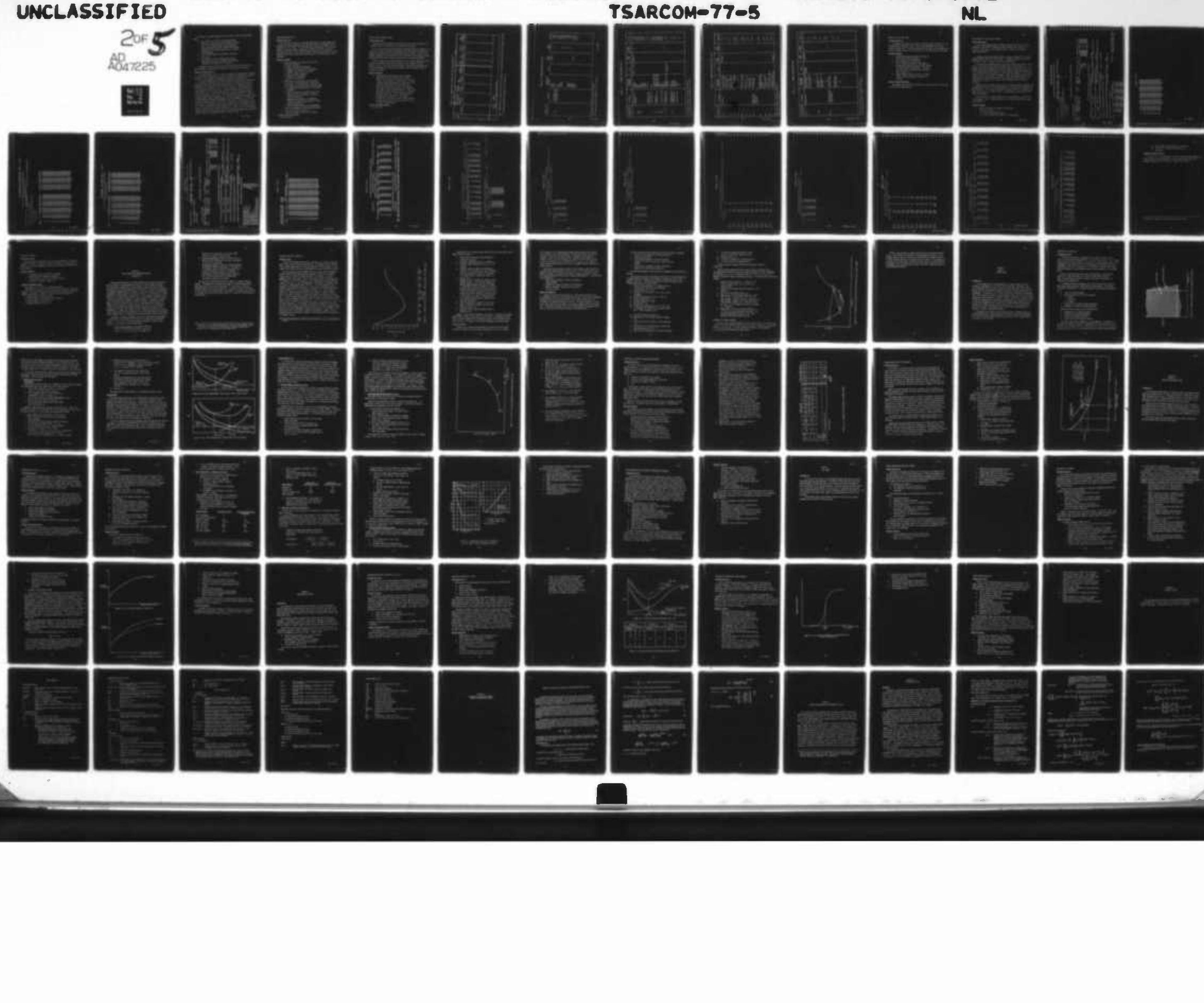

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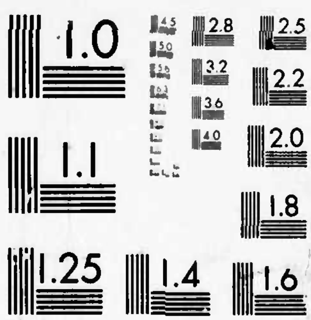

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

As currently programmed, AMSEC can be excercised in any of three optional modes.

a. It can deliver, as output, the component/system readiness, reliability, and maintainability factors only. This option would apply where component cost and spares output data is either unattainable because of lack of input information, or is simply not of interest.

b. It can provide output of cost/spares information only, and

c. It can provide a full presentation of mission readiness and reliability, together with material acquisition and support costs, and spares.

The output in each case can be varied, both in level of configuration at which estimates are provided and in degree of analytical detail provided.

Analysis by Type of Failure

For many analyses, there is a specific interest in determining the frequency of certain kinds of system failures and other causes for maintenance or support actions; or in estimating the corresponding support and operating costs.

In order to address these interests, AMSEC has been extended to categorize and array system maintenance actions in terms of (a) service, (b) preventive maintenance, (c) transportation and handling failure, (d) maintenance induced failures, and (e) mission failures. Mission failures are further broken down into categories called critical (e.g., failures hazarding system viability or safety), major (e.g., failures which prevent or seriously compromise chances of mission success), or minor (e.g., failures which have little or no impact on mission success); and to chargeable (e.g., failures stemming from component design of characteristics fabrication procedures), vs. non-chargeable (e.g., failures caused by improper handling or operation of the system). By using AMSEC to sum the component maintenance actions by cause (category) over all components we provide a basis for determining system support costs in total and further the distribution of the total to the various categories of interest. Cost per man hour and material costs by failure category are also separately tabulated, thus yielding as output projections by category of labor and material costs.

COLLECTION OF INPUT DATA

Problem Description

The first step in the use of the AMSEC RMAC Model is to draw together the parameter estimates appropriate to the particular stage of development of the system which is of interest. At this point these estimates will be on the work-sheets, as they were entered according to procedures set forth in Section I. They should be given a final review for general accuracy and applicability to the problem at hand, and any final modifications made on the current copies of the worksheets.

Analysis Procedure

1. Collect worksheets for each of the six input parameter categories:
   a. System configuration parameters
   b. Component life characteristic parameters
   c. Component maintainability parameters
   d. Logistic support parameters
   e. Operational use parameters
   f. Support cost procedures
2. Review data for completeness and consistency. A manual edit of the worksheets is carried out. As a minimum, the following checks should be made:
   a. Estimates have been entered for all pertinent parameters
   b. Ranges of values and histogram interval has been set forth for parameters requiring a sensitivity analysis
   c. Component mix corresponds to appropriate mission utilization, and to portion of total system being analyzed
   d. Check individual entries for reasonableness.
3. Check any discrepancies with cognizant engineer/ analyst and modify as required
4. Indicate acceptance of forms by initialing.

Computer Programming Summary

None required.

ENTRY OF DATA ON SUMMARY FORMS

Problem Description

The data as brought forward on the worksheets must now be aggregated into a summary format for convenience in reviewing and keypunching.

As a first step, these input parameters characterized by a distribution (i.e., a curve or a series of straight-line segments) must be examined to determine if some are sufficiently similar that the same input can be used. Curves will be assigned a number, and a table-look-up will be entered into the computer whereby each relevant curve can be called up by addressing the appropriate number.

After a table of curve forms (see Figure II.1a) has been completed, the data on the six worksheets should now be transferred onto a summary form (see Figure II.1b, c). This form is double-indexed to show both the worksheet name of the data element being entered from worksheet, and the keypunch blocks to be used on the cards.

Analysis Procedure

1. Develop the curve table data from the component maintainability and life characteristics worksheets. Each unique set of curve data are assigned a number of the worksheet and the unique curve data points are entered onto the curve table form.
2. Enter each finalized data element from worksheet onto summary format in appropriate box. Appropriate positions for placing decimal points are indicated; necessary codes (e.g., type of component hazard considered to be dominant) are also shown.
3. A manual edit of the data transfer operation should be made, to assure that the copy is error free and is placed in proper boxes.

Computer Programming Summary

None required.

FIGURE II.1a. SUMMARY SHEET FOR CURVE INPUT DATA FROM WORKSHEETS 1/

Curve No.		Card 2: NSIZE (No. of points) (No. of phases) Usually 1	Card 2: 0=Linear 1=Weibull 2=a,b	Card 2: NACC Usually 4	Card 2: Name (Optional)	Card 3: Not Used	Card 3: X,μ, or a	Card 3: Y,P(μ/2), or b	Card 3: Name Optional
	Columns	1-10	11-20	21-30	41-80	1-10	11-20	21-30	41-80
1									
2									
.									
.									
.									
N									
	CARD 1 - NCURVE Columns 1-10 (Number of curves read)								

NOTE: CARDS 2 and 3 are required for each curve description from component maintainability parameter worksheet.

1/ All terms are defined in Appendix C, pp. C-26 thru 29.

FIGURE II.1b. SUMMARY FORM FOR DATA INPUT

Worksheet Data Element [1/]	Worksheet	Input Data Element [2/]	Value	Data Deck	Card Number	Columns
		ITLE		Control	1	1-76
		IPR				77-80
ν	Operational use	NMISS			2	1-5
t	Operational use	T				6-10
Tau	Operational use	Tau				11-15
		EPS				16-25
		MISNAM				41-80
		MISDES			3	1-80
					4	1-80
					5	1-80
					6	1-80
		MISDES			7	1-80
		JDEL1			8	1-5
		JMAX1				6-10
		JDEL2		Control		11-15
		ISYS				16-20
		NCRIT				21-25

1/ All terms are defined in Glossary Appendix A.

2/ All terms are defined in Appendix C pp. C-26 thru 29.

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FIGURE II. . SUMMARY FORM FOR DATA INPUT.

Worksheet Data Element 1/	Worksheet	Input Data Element 2/	Value	Data Deck	Card Number	Columns
N	System configuration	NTYPES	(No. of sets)	Component	1	1-10
		IENAME			2	1-16
N_k		XNK				21-30
X_k		XXK				31-40
X'_k		XXKP				41-50
		MSPAR				51-60
		IFUNAM				68-80
		ICNAME			3	1-16
	Component life characteristics	NFAILS				21-25
ρ	Operational use	RHO				26-30
α	Component Maintainability	IALPHA-(curve no)				31-35
β		IBETAC-(curve no)				36-40
γ_1		IGAMM1-(curve no)				41-45
γ_2		IGAMM2-(curve no)				46-50
δ		DELTA				51-55
C_R	Logistics support	IRFRB				56-60
		UNIT				61-80
μ_i, $\mu_i/2$	Component Life Characteristics	MODTYP(1)			4	1
		IEVN01(1) curve no.	(set for each failure)			2-3
		IEVN02(1)				4-5
$C_{k,f}$	Operational use	ICR(1)				6
	Component Life Characteristics	MODTYP(2)				7
		IEVN01(2)				8-9
		IEVN02(2)				10-11
	Operational use	ICR(2)				12
		:				:
		Etc.				Etc.

1/ All terms are defined in Glossary, Appendix A.

2/ All terms are defined in Appendix C, p. C-26-29.

FIGURE II.1c. SUMMARY FORM FOR DATA INPUT (Cont)

Worksheet Data Element[1/]	Worksheet	Input Data Element[2/]	Value	Data Deck	Card Number	Columns
C_{k0}	Cost basis	Cost per service man-hours, CK(1)		Component	5	1-6
C_{k1}		Cost per PM man-hours, CK(2)				7-12
C_{k2}		Cost per CM man-hours,H/T,CK(3)				13-18
C'_{k0}		Material cost per service, CK(4)				19-24
C'_{k1}		Material cost per PM, CK(5)				25-30
C'_{k2}		Material cost per CM, for H/T, CK(6)				31-36
$C_{\bar{A}}$		Cost of unavailability CK(7)				37-42
$C_{\bar{R}}$		Cost of unreliability, CK(8)				43-48
h_{k0}	Component maintainability/ maintenance service	Man-hours per service, HK(1)				49-54
h_{k1}		Man-hours per PM maintenance, HK(2) renewal				55-60
h_{k2}		Man-hours per H/T failure, HK(3)				61-66
h_{k3}		Man-hours per mission failure, HK(4)				67-72
f_s		Useage hours per service action, HK(5)		Component		73-78

1/ All terms defined in Glossary, Appendix A.

2/ All terms defined in Appendix C.

FIGURE II.11c. SUMMARY FORM FOR DATA INPUT.

Worksheet Data Element 1/	Worksheet	Input Data Element 2/	Value	Data Deck	Card Number	Columns
$C_{K3,m}$	Cost basis	Cost per man hour for CM, CK3(1)	For each failure	Component	6	1-6
		Cost per man hour for CM, CK3(2)				7-12
		⋮ Etc.				⋮ Etc.
$C'_{K3,m}$		Material cost for CM, CK6(1)			7	1-6
		Material cost for CM, CK6(2)				7-12
		⋮ Etc.				⋮ Etc.
$h_{k,4,m}$	Component maintainability/maintenance service	Man hours per mission, HK4(1)			8	1-6
		Man hours per mission, HK4(2)				7-12
		⋮ Etc.				⋮ Etc.

1/ All terms are defined in Glossary, Appendix A.

2/ All terms are defined in Appendix C, p. C-26-29.

KEYPUNCH OF DATA ONTO CARDS

Problem Description

The summary data inputs as set forth on the form shown in Figure II.1 must be keypunched for computer input. This is a straightforward step, but one subject to human error. A verifying printout of the inputs by the computer prior to actual computer analysis will provide a basis for careful edit of the inputs.

Analysis Procedure

1. Keypunch each block as entered in Figure II.1 onto card for use with computer.
2. Enter punched cards into computer.
3. Call for computer playback of input data is automatically done by running the AMSEC program or the cost-spares model program. The form in which the inputs are summarized is the same as that in Figure II.1.
4. Review computer summary of inputs vs. manual summary. Make any necessary corrections in keypunch.

Computer Programming Summary

The computer subroutine which provides for a display printout of input data is a part of the AMSEC program.

SPECIFICATION OF DESIRED OUTPUT FORM(S)

Problem Description

In its normal operating mode, the AMSEC program will print out, for each component, a time-sequence of RMAC and spares estimates for a period of ν missions. Aggregation of the component values is carried out to provide system RMAC estimates.

A complete, illustrative AMSEC printout is shown in Appendix D for a simple system problem as defined in that Appendix. The general form of this output is displayed in Figure II.2 which is excerpted from Appendix D.

The analyst may, depending upon his particular interest at the time, elect to call up this entire output, or he may selectively call up only part of it. For example, he may not be interested in the RMAC change over time, but only in the steady-state values of RMAC toward which the system will approach with continued use. Or he may only be interested in a single specific mission; or in the values of RMAC, but not in the spares requirements. While the computer program traces through the same analysis steps in each case, the actual data printout can be controlled and in many cases limited to that information which is directly pertinent.

Generally, the total AMSEC operation over all missions would be desirable for problem solving prior to, or upon introduction of a new system on a component into operational use. For fielded systems which have been in use for a long period of time, the printout for a single value of ν corresponding to that period of time might be preferrable.

The specification of output format must thus be entered as an instruction to the computer. This is handled by the use of Job Control Language (JCL) cards (see Appendix C).

Analysis Procedure

1. Define limitations on problem to be solved by computer in terms of:
   (a) Mission number(s) of interest
   (b) Output variables (RMAC spares) to be suppressed

INPUT DATA FOR LITTLE ANNA

**********CUMPONENT/EQUIPMENT REQUIREMENTS**********

```
EQUIPMENT NAME ANNA          COMPONENT NAME LITTLE ANNA        FUNCTION CODE 52123456789 10
                         UTIL RATE 1.0000    FAILURE ARGUMNT HOURS

   NUMBER OF COMPONENTS IN EQUIPMENT                           2.

   NUMBER OF FUNCTIONING COMPONENTS REQUIRED FOR-

       MISSION READINESS                                       2.

       MISSION SUCCESS                                         1.
```

**********COMPONENT LIFE CHARACTERISTICS**********

```
   NUMBER OF FAILURE MODES          1

NUMBER OF FAILURE STAGES=    2 FOR MODE     1
STAGE    1     USES CURVE NO.      5          CURVE 5     LITTLE ANNA
  PHASE    1     STAGE 1     LITTLE ANNA                  WEIBUL   A=  0.330529E-08 B= 2.7801  MU=   1000.00 P(MU/2)= 0.9000
STAGE    2     USES CURVE NO.      6          CURVE 6    LITTLE ANNA
  PHASE    1     STAGE2     LITTLE ANNA                   WEIBUL   A=  0.426451E-11 B= 3.7348  MU=   1000.00 P(MU/2)= 0.9500
                                                                                  1/4 MU=          500.0000      P=   0.99980
                                                                                  1/2 MU=         1000.0000      P=   0.98354
                                                                                  3/4 MU=         1500.0000      P=   0.84290
                                                                                      MU=         2000.0000      P=   0.49247
                                                                                  3/2 MU=         3000.0000      P=   0.02295
                                                                                   2  MU=         4000.0000      P=   0.00003
                                                                                                              A
```

**********MAINTENANCE FREQUENCY CHARACTERISTICS**********

```
   PROBABILITY OF NO PREVENTIVE MAINTENANCE WITH COMPONENT USE(BETA)
                                                                USES CURVE NO.     2 CURVE 2    LITTLE ANNA
  PHASE    1   BETA       LITTLE ANNA                     WEIBUL   A=  0.597494E-15 B= 5.0127  MU=   1000.00 P(MU/2)= 0.9800

   PROBABILITY OF INITIATING PREVENTIVE MAINTENANCE WITH COMPONENT USE(GAMMA1)
                                                                USES CURVE NO.     3 CURVE 3    LITTLE ANNA
  PHASE    1    GAMMA1     LITTLE ANNA                    WEIBUL   A=  0.597494E-15 B= 5.0127  MU=   1000.00 P(MU/2)= 0.9800

   PROBABILITY OF COMPLETING PREVENTIVE MAINTENANCE(GAMMA2)=   0.993262
                                                                USES CURVE NO.     4 CURVE 4    LITTLE ANNA

   PROBABILITY OF HANDLING/TRANSPORTATION FAILURE(1-DELTA)=   0.020000

   PROBABILITY OF COMPLETING CORRECTIVE MAINTENANCE FOLLOWING MISSION FAILURE(ALPHA)=   1.000000
                                                               USES CURVE NO.     1 CURVE 1    LITTLE ANNA

   COMPONENT REBUILDING CYCLE=    25 (MISSION)
```

MISSION	USAGE	SURVIVAL	PREVENTIVE MAINTENANCE NONE	COMPLETE	INCOMPLETE
1	100.00	1.000000	0.999994	0.000006	0.000000
2	200.00	0.999999	0.999795	0.000203	0.000001
3	300.00	0.999992	0.998440	0.001549	0.000011
4	400.00	0.999752	0.993419	0.006536	0.000044
5	500.00	0.997795	0.979957	0.019869	0.000135
6	600.00	0.999335	0.950853	0.048016	0.000331
		B1	B2	B3	B4

FIGURE II.2. RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

FIGURE II.2 (Cont)

		B_1	B_2	B_3	B_4
7	700.00	0.998217	0.896604	0.102699	0.000697
8	800.00	0.995850	0.800035	0.190671	0.001293
9	900.00	0.991352	0.680671	0.317177	0.002152
10	1000.00	0.983536	0.520835	0.475937	0.003229
11	1100.00	0.970938	0.349290	0.646325	0.004384
12	1200.00	0.951966	0.196527	0.798059	0.005414
13	1300.00	0.925056	0.088027	0.905829	0.006145
14	1400.00	0.888943	0.029500	0.963961	0.006539
15	1500.00	0.842897	0.006880	0.986429	0.006692
16	1600.00	0.786921	0.001027	0.992242	0.006731
17	1700.00	0.721875	0.000089	0.993173	0.006737
18	1800.00	0.649454	0.000004	0.993258	0.006738
19	1900.00	0.572040	0.000000	0.993262	0.006738
20	2000.00	0.492472	0.000000	0.993262	0.006738
21	2100.00	0.413764	0.000000	0.993262	0.006738
22	2200.00	0.338762	0.000000	0.993262	0.006738
23	2300.00	0.269900	0.000000	0.993262	0.006738
24	2400.00	0.208369	0.000000	0.993262	0.006738
25	2500.00	0.157025	0.000000	0.993262	0.006738

RAM ASSESSMENT FOR SUBSYSTEM ANNA FIGURE II.2 (Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT RESULTS VERSUS AGE

COMPONENT NAME LITTLE ANNA FUNCTION CODE 52123456789 10

EQUIPMENT NAME ANNA UTIL RATE 1.0000 FAILURE ARGUMNT HOURS

NUMBER OF COMPONENTS IN EQUIPMENT 2.

NUMBER OF FUNCTIONING COMPONENTS REQUIRED FOR-

MISSION READINESS 2.

MISSION SUCCESS 1.

MISSION NUMBER	USAGE	MISSION ACCOMPLSH	MISSION READINESS	MISSION RELIABLTY	AVERAGE ACCOMPLSH	AVERAGE READINESS	AVERAGE RELIABLTY
1	100.0	0.960400	0.960400	1.000000	0.960400	0.960400	1.000000
2	200.0	0.960400	0.960400	1.000000	0.960400	0.960400	1.000000
3	300.0	0.960397	0.960397	1.000000	C.960399	0.960399	0.999999
4	400.0	0.960381	0.960381	1.000000	C.960394	0.960394	0.999999
5	500.0	0.960321	0.960321	1.000000	0.960379	0.960379	0.999999
6	600.0	0.960166	0.960166	1.00000C	C.960344	0.960344	0.999999
7	700.0	0.959845	0.959846	0.999999	0.960272	0.960272	0.999999
8	800.0	0.959307	0.959310	C.999997	0.960152	0.960152	0.999999
9	900.0	0.958609	0.958616	0.999993	0.959980	0.959981	0.999998
10	1000.0	0.958026	0.958035	0.999990	0.959785	C.959787	0.999997
11	1100.0	0.957989	0.957995	0.999993	C.959621	0.959624	0.999997
12	1200.0	0.958640	0.958642	C.999997	C.959540	0.959542	0.999997
13	1300.0	0.959467	0.959468	0.999999	0.959534	0.959536	0.999997
14	1400.0	0.959861	0.959861	1.000000	0.959557	0.959559	0.999997
15	1500.0	0.959814	0.959815	C.999999	0.959574	0.959576	0.999997
16	1600.0	0.959582	0.959583	C.999999	0.959575	0.959577	0.999997
17	1700.0	0.959278	0.959280	0.999998	0.959557	0.959559	0.999997
18	1800.0	0.958971	0.958975	0.999996	0.959524	0.959526	0.999997
19	1900.0	0.958749	0.958753	0.999996	0.959483	C.959485	0.999996
20	2000.0	0.958692	0.958697	0.999996	0.959443	0.959445	0.999995
21	2100.0	0.958826	0.958829	0.999997	0.959413	0.959415	0.999995
22	2200.0	0.959078	0.959080	0.999998	0.959398	C.959400	0.999994
23	2300.0	0.959322	0.959323	C.999998	0.959394	0.959396	0.999994
24	2400.0	0.959443	0.959445	C.959999	C.959396	C.959398	0.999994
25	2500.0	0.959416	0.959417	0.999998	0.959397	0.959399	0.999993
		C_1	C_2	C_3		C_4	

RAM ASSESSMENT FOR SYSTEM FIGURE II.2 (Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

SYSTEM RESULTS VERSUS AGE

MISSION NUMBER	USAGE	*********** MISSION ACCOMPLSH	READINESS	********** RELIABLTY	*********** AVERAGE ACCOMPLSH	READINESS	********** RELIABLTY
1	100.0	0.877619	0.877673	C.999939	0.877619	0.877673	0.999939
2	200.0	0.875882	0.876534	0.999255	0.876750	0.877103	0.999597
3	300.0	0.872825	0.875250	0.997229	0.875441	0.876485	0.998807
4	400.0	0.866523	0.872197	C.993494	0.873211	0.875413	0.997479
5	500.0	0.856770	0.867027	0.988169	0.869923	0.873736	0.995617
6	600.0	0.844688	0.860057	0.982085	0.865717	0.871462	0.993361
7	700.0	0.833013	0.852754	0.976850	0.861045	0.868790	0.991003
8	800.0	0.825418	0.847143	0.974355	0.856592	0.866084	0.988922
9	900.0	0.824572	0.845202	0.975592	0.853034	0.863764	0.987441
10	1000.0	0.829919	0.847227	0.979571	0.850722	0.862110	0.986654
11	1100.0	0.837376	0.851266	0.983684	0.849509	0.861124	0.986383
12	1200.0	0.841913	0.854196	0.985620	0.848876	C.860547	0.986320
13	1300.0	0.844799	0.855544	0.986288	0.848562	0.860239	0.986317
14	1400.0	0.836572	0.850929	0.983127	0.847706	0.859574	0.986089
15	1500.0	0.829276	0.845483	0.980831	0.846477	0.858634	0.985739
16	1600.0	0.824218	0.841274	0.979726	0.845086	0.857549	0.985363
17	1700.0	0.822024	0.838990	0.979778	0.843729	0.856457	0.985034
18	1800.0	0.822559	0.838837	0.980594	0.842553	0.855479	0.984787
19	1900.0	0.825050	0.840510	0.981606	0.841632	0.854691	0.984619
20	2000.0	0.828350	0.843263	0.982315	0.840968	0.854119	0.984504
21	2100.0	0.831299	0.846114	0.982490	0.840507	0.853737	0.984408
22	2200.0	0.833120	0.848221	0.982198	0.840171	0.853486	0.984307
23	2300.0	0.833668	0.849209	C.981698	0.839888	0.853299	0.984193
24	2400.0	0.833365	0.849264	0.981279	0.839616	0.853131	0.984072
25	2500.0	0.832830	0.848862	0.981113	0.839344	0.852960	0.983953
		C_1	C_2	C_3		C_4	

FIGURE II.2 (Cont)

```
                         *****COMPONENT/EQUIPMENT REQUIREMENTS******

EQUIPMENT NAME ANNA              COMPONENT NAME LITTLE ANNA        FUNCTION CODE 52123456789 10
                              UTIL RATE 1.0000   FAILURE ARGUMNT  HOURS

    NUMBER OF COMPONENTS IN EQUIPMENT                             2.

    MAXIMUM SPARES                                                0

                          **********COMPONENT LIFE CHARACTERISTICS**********

    NUMBER OF FAILURE MODES         1

NUMBER OF FAILURE STAGES=    2 FOR MODE    1    CRITICALITY=    2
STAGE    1     USES CURVE NO.     5            CURVE 5    LITTLE ANNA
               STAGE 1    LITTLE ANNA                     WEIBUL   A=  0.330529E-08 B= 2.7801  MU=   1000.00 P(MU/2)= C.9000
STAGE    2     USES CURVE NO.     6            CURVE 6   LITTLE ANNA
               STAGE2    LITTLE ANNA                      WEIBUL   A=  0.426451E-11 B= 3.7348  MU=   1000.00 P(MU/2)= 0.9500
                                                                                  1/4 MU=        500.0000     P=   0.99980
                                                                                  1/2 MU=       1000.0000     P=   0.98354
                                                                                  3/4 MU=       1500.0000     P=   0.84290
                                                                                      MU=       2000.0000     P=   0.49247
                                                                                  3/2 MU=       3000.0000     P=   0.02295
                                                                                   2  MU=       4000.0000     P=   0.00003
                                                                                                          A
                       **********MAINTENANCE FREQUENCY CHARACTERISTICS**********

    PR ABILITY OF NO PREVENTIVE MAINTENANCE WITH COMPONENT USE(BETA)
                                                           USES CURVE NO.     2 CURVE 2    LITTLE ANNA
               BETA      LITTLE ANNA                      WEIBUL   A=  0.597494E-15 B= 5.0127  MU=   1000.00 P(MU/2)= 0.9800

    PROBABILITY OF INITIATING PREVENTIVE MAINTENANCE WITH COMPONENT USE(GAMMA1)
                                                          USES CURVE NO.     3 CURVE 3    LITTLE ANNA
               GAMMA1    LITTLE ANNA                      WEIBUL   A=  0.597494E-15 B= 5.0127  MU=   1000.00 P(MU/2)= 0.9800

    PROBABILITY OF COMPLETING PREVENTIVE MAINTENANCE(GAMMA2)=  C.993262
                                                           USES CURVE NO.     4 CURVE 4    LITTLE ANNA

    PROBABILITY OF HANDLING/TRANSPORTATION FAILURE(1-DELTA)=  0.020000

    PROBABILITY OF COMPLETING CORRECTIVE MAINTENANCE FOLLOWING MISSION FAILURE(ALPHA)=  1.000000
                                                          USES CURVE NO.     1 CURVE 1    LITTLE ANNA

                       **********COST ANC HOURS CATA**********

COST PER SERVICE MAN HCUR                             11.60
COST PER PM MAN HOUR                                  11.60
COST PER CM MAN HCUR FCR H/T                          11.60
MATERIAL COST PER SERVICE                            100.00
MATERIAL COST PER PM                                1000.00
MATERIAL COST PER CM FOR H/T                        2000.00
CCST UNAVAILABLE                                    2000.00
CCST UNRELIABLE                                    50000.00
MAN HCURS PER SERVICE                                  1.00
MAN HCURS PER PM                                      10.00
MAN HOURS PER H/T FAILURE                             10.00
MAN HOURS PER MISSION FAILURE(NOT USED)                C.0
OPERATING INTERVAL PER SERVICE ACTICN                 20.00
```

FIGURE II.2 (Cont)

COST PER CM MAN HOUR BY MODE 11.600
MATERIAL COST PER CM BY MODE 2000.000
MAN HOURS MISS FAIL BY MODE 10.000

MISSION	USAGE	SURVIVAL	PREVENTIVE MAINTENANCE NONE	COMPLETE	INCOMPLETE	MODE INTEGRALS
1	100.00	1.000000	0.999994	0.000006	0.000000	0.0000
2	200.00	0.999999	0.999795	0.000203	0.000001	0.0000
3	300.00	0.999952	0.998440	0.001549	0.000011	0.0000
4	400.00	0.999952	0.993419	0.006536	0.000044	0.0000
5	500.00	0.999795	0.979597	0.019869	0.000135	0.0002
6	600.00	0.999335	0.950353	0.048816	0.000331	0.0005
7	700.00	0.998217	0.896504	0.102699	0.000697	0.0011
8	800.00	0.995850	0.808035	0.190671	0.001293	0.0024
9	900.00	0.991352	0.680671	0.317177	0.002152	0.0045
10	1000.00	0.983536	0.520835	0.475937	0.003229	0.0078
11	1100.00	0.970938	0.349290	0.646325	0.004384	0.0126
12	1200.00	0.951966	0.196527	0.798059	0.005414	0.0190
13	1300.00	0.925056	0.088027	0.905829	0.006145	0.0269
14	1400.00	0.888943	0.029500	0.963961	0.006539	0.0361
15	1500.00	0.842897	0.006880	0.986429	0.006692	0.0461
16	1600.00	0.786921	0.001027	0.992242	0.006731	0.0560
17	1700.00	0.721875	0.000089	0.993173	0.006737	0.0650
18	1800.00	0.649454	0.000004	0.993258	0.006738	0.0724
19	1900.00	0.572040	0.000000	0.993262	0.006738	0.0774
20	2000.00	0.492472	0.000000	0.993262	0.006738	0.0796
21	2100.00	0.413764	0.000000	0.993262	0.006738	0.0787
22	2200.00	0.338762	0.000000	0.993262	0.006738	0.0749
23	2300.00	0.269900	0.000000	0.993262	0.006738	0.0686
24	2400.00	0.208969	0.000000	0.993262	0.006738	0.0606
25	2500.00	0.157025	0.000000	0.993262	0.006738	0.0514
		B_1	B_2	B_3	B_4	

FIGURE II.2 (Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT ANNA FUNCTICN CCDE 52123456789 10 STATISTICS FOR MISSIONS 2 COMPCNENT(S)

EXPECTED MAINTENANCE ACTIONS BY TYPE

MISSIONS	SERVICE ACTIONS	COMPLETE PMA'S	INCOMPLET PMA'S	COMPLETE CMA'S	INCOMPLET CMA'S	HAND/TRA CMA'S	MIS FAIL CMA'S	COMPLETE MA'S	INCOMPLET MA'S	TOTAL MA'S
1	10.00	0.00	0.0	0.04	0.0	0.04	0.00	0.04	0.0	0.04
2	20.00	0.00	0.00	0.08	0.0	0.08	0.00	0.08	0.00	0.08
3	30.00	0.00	0.00	0.12	0.0	0.12	0.00	0.12	0.00	0.12
4	40.00	0.02	0.00	0.16	0.0	0.16	0.00	0.18	0.00	0.18
5	50.00	0.05	0.00	0.20	0.0	0.20	0.00	0.25	0.00	0.25
6	60.00	0.14	0.00	0.24	0.0	0.24	0.00	0.38	0.00	0.38
7	70.00	0.30	0.00	0.28	0.0	0.28	0.00	0.59	0.00	0.59
8	80.00	0.58	0.00	0.33	0.0	0.32	0.01	0.90	0.00	0.91
9	90.00	0.94	0.00	0.37	0.0	0.36	0.01	1.31	0.00	1.32
25	250.00	4.00	0.03	1.06	0.0	1.00	0.06	5.06	0.03	5.09

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT ANNA FUNCTICN CODE 52123456789 10 COST STATISTICS FOR MISSIONS 2 COMPONENT(S)

MISS	****SERVICE ACTION*****			***PREVENTIVE MAINT****			***CORRECTIVE MAINT****			*******TOTAL*********			UNAVAIL-	UNRELI-
IONS	LABOR	MATERIAL	TOTAL	LABOR	MATERIAL	TOTAL	LABOR	MATERIAL	TOTAL	LABOR	MATERIAL	TOTAL	ABLE	ABLE

FIGURE II.2. Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT ANNA FUNCTION CODE 52123456789 1) COST STATISTICS FOR MISSIONS 2 COMPONENT(S)

MISS IONS	****SERVICE ACTION***** LABOR	MATERIAL	TOTAL	***PREVENTIVE MAINT**** LABOR	MATERIAL	TOTAL	***CORRECTIVE MAINT*** LABOR	MATERIAL	TOTAL	*******TOTAL******* LABOR	MATERIAL	TOTAL	UNAVAIL- ABLE	UNSELI- ABLE
1	116.	1000.	1116.	0.	0.	0.	5.	80.	85.	121.	1080.	1201.	0.	0.
2	232.	2000.	2232.	0.	0.	0.	9.	160.	169.	241.	2160.	2402.	0.	0.
3	348.	3000.	3348.	0.	3.	4.	14.	240.	254.	362.	3243.	3606.	0.	1.
4	464.	4000.	4464.	2.	15.	17.	19.	320.	339.	484.	4336.	4820.	0.	4.
5	580.	5000.	5580.	6.	51.	57.	23.	401.	424.	609.	5452.	6061.	0.	19.
6	696.	6000.	6696.	16.	137.	153.	28.	482.	510.	740.	6619.	7359.	1.	59.
7	812.	7000.	7812.	35.	305.	340.	33.	566.	599.	880.	7870.	8751.	2.	149.
8	928.	8000.	8928.	67.	580.	647.	38.	653.	691.	1033.	9232.	10265.	4.	319.
9	1044.	9000.	10044.	110.	945.	1054.	43.	743.	786.	1197.	10687.	11884.	8.	577.
25	2900.	25000.	27900.	467.	4028.	4495.	123.	2120.	2243.	3490.	31147.	34637.	52.	3021.

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

COMPONENT LITTLE ANNA FUNCTION CODE 52123456789 10 IS USED 4 TIME(S) ON 25 MISSION(S) WITH 25 SPARE(S) MAX

SPARES	PROBABILITY	CUM PROBABILITY
7	0.00022228	0.00022228
8	0.07598603	0.07620829
9	0.23762965	0.31383795
10	0.31367493	0.62751287
11	0.22913784	0.85665071
12	0.10364622	0.96029693
13	0.03143092	0.99172783
14	0.00689837	0.99862617
15	0.00116412	0.99979025
16	0.00015804	0.99994826
	D_1	D_2

FIGURE II.2. (Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT ANNA FUNCTION CODE 52123456789 10 STATISTICS FOR MISSIONS 2 COMPONENT(S)

EXPECTED CORRECTIVE MAINTENANCE ACTIONS BY CRITICALITY CODE

MISSIONS	MIS FAIL CMA'S	CODE 1	CODE 2
1	0.00	0.0	0.00
2	0.00	0.0	0.00
3	0.00	0.0	0.00
4	0.00	0.0	0.00
5	0.00	0.0	0.00
6	0.00	0.0	0.00
7	0.00	0.0	0.00
8	0.01	0.0	0.01
9	0.01	0.0	0.01
25	0.06	0.0	0.06

FIGURE II.2. (Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT ANNA   FUNCTION CODE 52123456789 1)   STATISTICS FOR MISSIONS 2 COMPONENT(S)

EXPECTED CORRECTIVE MAINTENANCE ACTIONS BY FAILURE MODE

MISSIONS	HAND/TRA	MODE 1
1	0.04	0.00
2	0.08	0.00
3	0.12	0.00
4	0.16	0.00
5	0.20	0.00
6	0.24	0.00
7	0.28	0.00
8	0.32	0.01
9	0.36	0.01
25	1.00	0.06

FIGURE II.2. (Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT ANNA FUNCTION CODE 52123456789 TO COST STATISTICS FOR MISSIONS BY FAILURE MODE 2 COMPONENT(S)

	MISSIONS	HAND/TRA	MODE 1
LABOR	1	5.	0.
MATERIAL		80.	0.
TOTAL		85.	0.
LABOR	2	9.	0.
MATERIAL		160.	0.
TOTAL		169.	0.
LABOR	3	14.	0.
MATERIAL		240.	0.
TOTAL		254.	0.
LABOR	4	19.	0.
MATERIAL		320.	0.
TOTAL		339.	0.
LABOR	5	23.	0.
MATERIAL		400.	1.
TOTAL		423.	1.
LABOR	6	28.	0.
MATERIAL		480.	2.
TOTAL		508.	2.
LABOR	7	32.	0.
MATERIAL		560.	6.
TOTAL		592.	6.
LABOR	8	37.	1.
MATERIAL		640.	13.
TOTAL		677.	14.
LABOR	9	42.	1.
MATERIAL		720.	23.
TOTAL		762.	24.
LABOR	25	116.	7.
MATERIAL		1999.	121.
TOTAL		2115.	128.

FIGURE II.2. (Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EXPECTED TOTAL SYSTEM MAINTENANCE ACTIONS BY CRITICALITY 2 SYSTEM(S)

MISSIONS	MIS FAIL CMA'S	CRIT 1	CRIT 2
1	0.00	0.00	0.00
2	0.00	0.00	0.00
3	0.01	0.00	0.01
4	0.02	0.00	0.02
5	0.04	0.00	0.04
6	0.08	0.01	0.08
7	0.13	0.01	0.12
8	0.19	0.02	0.17
9	0.25	0.04	0.22
25	1.77	0.99	0.78

FIGURE II.2. (Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

SYSTEM COST FOR CORRECTIVE MAINTENANCE BY CRITICALITY 2 SYSTEM(S)

	MISSIONS	MAHC/TRA	CRIT 1	CRIT 2
LABOR	1	124.	0.	0.
MATERIAL		2147.	0.	0.
TOTAL		2271.	0.	0.
LABOR	2	250.	0.	0.
MATERIAL		4306.	0.	3.
TOTAL		4555.	0.	3.
LABOR	3	375.	0.	1.
MATERIAL		6465.	0.	14.
TOTAL		6840.	0.	15.
LABOR	4	500.	0.	2.
MATERIAL		8624.	1.	40.
TOTAL		9125.	1.	42.
LABOR	5	625.	0.	5.
MATERIAL		10784.	4.	85.
TOTAL		11409.	4.	90.
LABOR	6	751.	1.	9.
MATERIAL		12943.	10.	153.
TOTAL		13694.	11.	162.
LABOR	7	876.	1.	14.
MATERIAL		15102.	23.	240.
TOTAL		15978.	24.	254.
LABOR	8	1001.	3.	20.
MATERIAL		17261.	43.	337.
TOTAL		18262.	46.	357.
LABOR	9	1126.	4.	25.
MATERIAL		19419.	72.	434.
TOTAL		20546.	76.	459.
LABOR	25	3124.	115.	91.
MATERIAL		53868.	1980.	1565.
TOTAL		56993.	2095.	1656.

FIGURE II.2. (Cont)

RAP AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EXPECTED TOTAL SYSTEM MAINTENANCE ACTIONS BY TYPE 2 SYSTEM(S)

MISS IONS	SERVICE ACTIONS	TOTAL MA'S	COMPLETE MA'S	INCOMPLET MA'S	TOTAL PMA'S	COMPLETE PMA'S	INCOMPLET PMA'S	TOTAL CMA'S	COMPLETE CMA'S	INCOMPLET CMA'S	HAND/ILA CMA'S	MIS FAIL CMA'S
1	130.00	1.08	1.07	0.01	0.00	0.00	0.0	1.07	1.07	0.01	1.07	0.00
2	260.00	2.17	2.16	0.01	0.02	0.02	0.00	2.15	2.14	0.01	2.15	[illegible]
3	390.00	3.31	3.28	0.02	0.07	0.06	0.00	3.24	3.22	0.02	3.23	0.01
4	520.00	4.52	4.48	0.04	0.19	0.17	0.01	4.33	4.31	0.03	4.31	0.02
5	650.00	5.87	5.80	0.07	0.43	0.40	0.04	5.44	5.40	0.03	5.39	0.04
6	780.00	7.42	7.30	0.12	0.86	0.79	0.08	6.55	6.51	0.04	6.47	0.08
7	910.00	9.23	9.05	0.18	1.54	1.41	0.13	7.68	7.64	0.05	7.55	0.13
8	1040.00	11.32	11.06	0.26	2.50	2.30	0.20	8.82	8.77	0.05	8.63	0.19
9	1170.00	13.63	13.29	0.34	3.67	3.39	0.28	9.96	9.90	0.06	9.71	0.25
25	3250.00	54.27	52.05	2.22	25.56	23.52	2.04	28.71	28.53	0.17	26.93	1.77

FIGURE II.2 (Cont)

RAM AMSEE PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

SYSTEM SUPPORT COST   2 SYSTEM(S)

MISSIONS	****SERVICE ACTION***** LABOR	MATERIAL	TOTAL	***PREVENTIVE MAINT**** LABOR	MATERIAL	TOTAL	***CORRECTIVE MAINT**** LABOR	MATERIAL	TOTAL	********TOTAL********* LABOR	MATERIAL	TOTAL	UNAVAIL-ABLE	UNRELI-ABLE
1	1508.	13000.	14508.	0.	2.	2.	125.	2147.	2271.	1633.	15149.	16781.	13.	6.
2	3016.	26000.	29016.	2.	16.	18.	250.	4309.	4559.	3268.	30325.	33593.	28.	81.
3	4524.	39000.	43524.	8.	66.	73.	376.	6479.	6855.	4907.	45545.	50453.	48.	359.
4	6032.	52000.	58032.	22.	187.	209.	503.	8665.	9168.	6556.	60852.	67408.	82.	1015.
5	7540.	65000.	72540.	50.	432.	483.	631.	10872.	11503.	8221.	76305.	84526.	141.	2220.
6	9048.	78000.	87048.	100.	865.	965.	760.	13106.	13866.	9908.	91971.	101879.	231.	4080.
7	10556.	91000.	101556.	179.	1545.	1724.	891.	15365.	16256.	11626.	107909.	119536.	357.	6570.
8	12064.	104000.	116064.	290.	2498.	2788.	1023.	17641.	18665.	13377.	124140.	137517.	511.	9514.
9	13572.	117000.	130572.	426.	3669.	4094.	1156.	19925.	21080.	15153.	140593.	155746.	679.	12633.
25	37700.	325000.	362700.	2965.	25564.	28529.	3330.	57414.	60744.	43995.	407977.	451972.	4432.	88637.

(c) Failure modes to be broken out, or suppressed

(d) Limitation of components/subsystems to be considered.

Computer Programming Summary

Partial control and suppression of printout is accomplished through selection of de-bug vs no de-bug made; full control and/or suppression can be handled through the use of Job Control Language (JCL) cards. 1/

1/ Appendix C provides a current listing of the JCL cards.

OPERATION OF COMPUTER

Problem Description

The actual AMSEC calculations carried out by the computer are fully programmed. The analysis involved is referenced in Appendix C and new updated algorithms set forth; programming cards have been provided to AVSCOM-PA under separate cover.

Analysis Procedure

1. All analysis steps are internal to the AMSEC computer program, referenced in Appendix C.
2. An illustrative printout of a full AMSEC analysis is shown for reference in Appendix D.

Computer Programming Summary

See Appendix C for referral to programming details.

The program is written in Fortran, for use on the IBM 360 or equivalent computer. JCL cards are required for specification of output by the various computer installations. Capacity limitations of present program are:

a. Maximum number of subsystems: None
b. Maximum number of failure modes for subsystem: 10
c. Maximum number of missions: 5,000
d. Maximum number of curves: 100

SECTION III
APPLICATIONS FOR PLANNING AND DECISION
INTRODUCTION

The one-step application of the AMSEC RMAC Model described in the previous Section provides a system/component evaluation, in terms of RMAC and spares, for the particular combination of input parameter values which were selected. The basic nature of the management planning problem is to examine the consequences of alternative combinations of parameters, and to select the most cost-effective combination. AMSEC, because of its analytic nature, is ideally suited to a rapid appraisal of the alternatives presented to it. The sequence of alternatives for evaluation can represent changes in a single variable, with others held constant, or it can represent joint changes in several variables. Furthermore, through AMSEC, the analyst can evaluate the trend of cost-effectiveness created by a sequence of such changes--in essence, measure the slope of a multi-dimensional surface--and from this decide whether further change would be useful, which parameter(s) to change, and in what direction. AMSEC can thus be used to selectively converge on the "best" combination of those variables which are considered free to change, within the constraints defined by parameters which are held fixed.

The number of required management decisions and evaluations to which AMSEC can contribute is quite large, and cuts across all stages of the development process. A cross-section of these problems was presented in Table 1, page 3. Basically, the problems fall into three classes:

1. Single-step evaluation, an assessment of RMAC and spares for a specified combination of input parameters. This is handled by a single AMSEC run,

delivering an output either in the normal AMSEC format or in a special-purpose format.

2. Multiple evaluations of specified alternatives, to develop values of RMAC/spares for each, for purposes of trade-off or comparison.
3. Sensitivity analysis of single or multiple parameters to determine "optimal" combinations. This makes use of the AMSEC executive routine to converge on the solution; the process involves (a) organized manipulation of input parameter values, thresholds, etc., and (b) iterative use of the RMAC model, followed by assessment and feedback.

This section describes the application of AMSEC to a range of problem classes. The problems are organized by the stage in the development process when they are most likely to be significant.[10/] In each case, sufficient procedural detail and illustrative material is provided to permit the analyst to set up and solve the stated problem, and further, to recognize other problems of the same class to which the same procedures--or slightly modified procedures--are applicable.

[10/] Note that the same problem type may recur during different stages of system development. Where the analytic approach is the same, the problem is only discussed once; the reader is referred to the Table of Contents for a complete list of problems which are described herein.

THE BASIC SENSITIVITY ANALYSIS

Single Variable

Many of the management applications, occurring at all stages of development, involve the use of sensitivity analysis. Consequently, before entering into a detailed description of individual problems, a brief discussion is presented of the process involved in using AMSEC for a basic sensitivity analysis.

The one-step application of AMSEC calls for entering into the computer a specific value for each required input parameter, to obtain as an output a single value--or history of values--of R,M,A,C, and spares, S, for each component and for the system. If all of the inputs are held fixed except the i^{th} variable, X_i, and if a new value of X_i is entered, then corresponding new values, R_i, M_i, A_i, C_i, and S_i are generated. By stepping X_i through a series of values, a corresponding series of R, M, A, C and S is generated by the computer, and the analyst can measure or draw curves to show the "sensitivity" of each of the R, M, A, C, and S outputs to change in X_i. As an example, Figure III.1 shows the sensitivity of cost to changes in overhaul interval. Cost in this case is defined to include both support cost and mission failure cost. It will be noted that variation in TBO produces a corresponding variation in C, all other parameters being held fixed. To obtain the curve, the value of TBO[11/] entered into AMSEC was progressively varied, in increments of 50 hours, from 0 to 500 flying hours. At the moment, the process of obtaining a new point on the curve involves manually inserting a new input card into the computer showing the new value of the independent parameter, and carrying out a new AMSEC run to obtain new values of the outputs. However the procedure is simple, and it is expected that early extensions of AMSEC will provide the sensitivity analysis as an automatic feature.

11/ The TBO corresponds to the mean of the distribution, $\gamma_{1k}(t)$, as discussed in Section I.

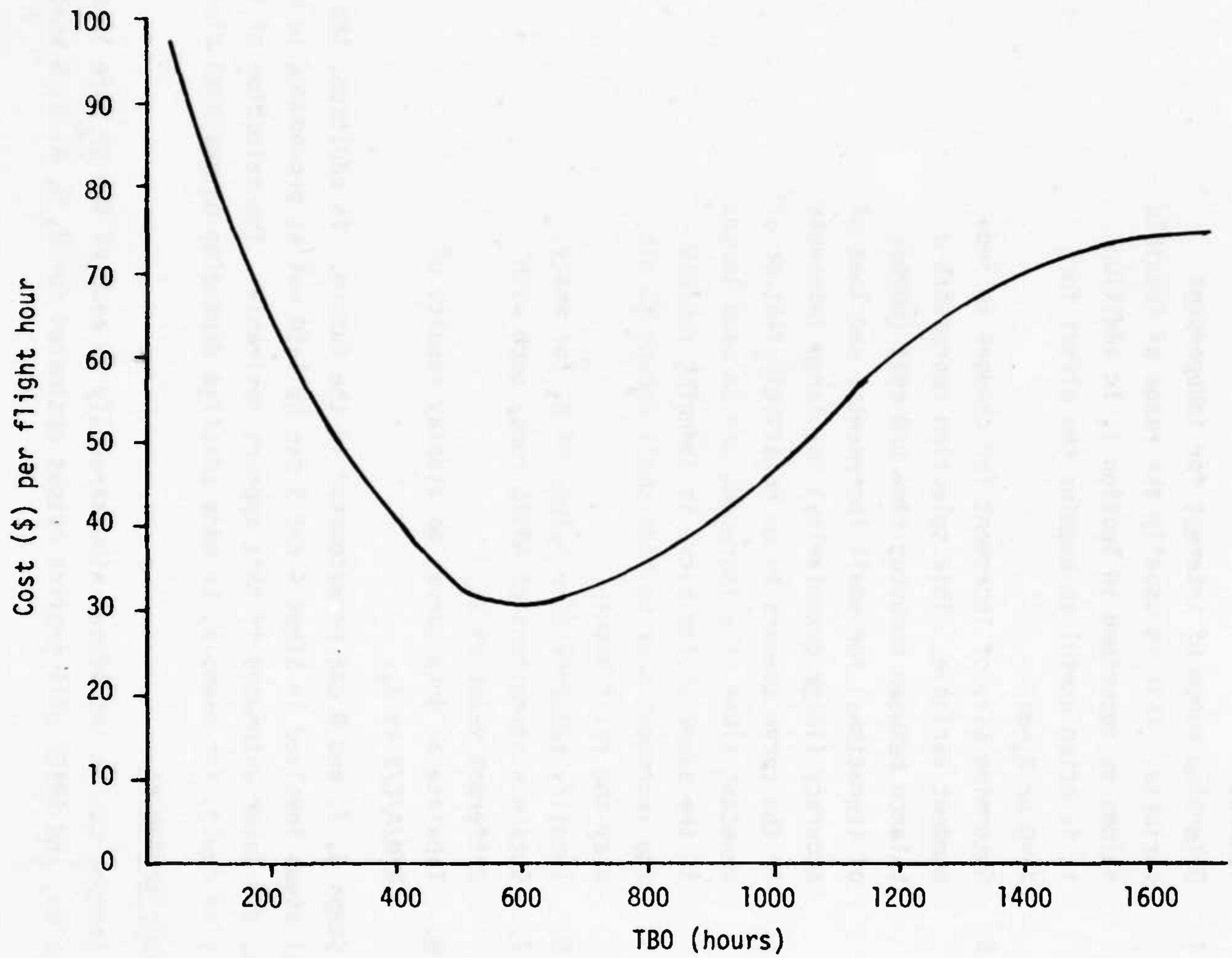

FIGURE III.1. SENSITIVITY OF COST (SUPPORT + MISSION FAILURE) TO CHANGES IN TBO

The procedures for a single-variable sensitivity run are as follows, using manual executive routine:

1. Select nominal values for input parameters as described in Section I.
2. Determine independent variable of interest, X_i.
3. Determine output measure(s) (R, M, A, C, S) of interest.
4. Determine range of interest for independent variable. This is usually the range of feasible values as described in Section I. In addition, it is often useful to examine the effect for X_i=0 or $X_i=\infty$.
5. Determine size of increment for changes in independent variable. This selection represents a balance between computer time and cost (number of iterations) for small increments, and loss of accuracy (large granularity) for large intervals. If the curve appears to be relatively flat or of constant slope, the increment can be made large; if the slope of the curve is changing rapidly the increment must be made small enough to display the relationship.
6. Identify sequence of n values of X_i for entry.
7. Obtain n iterations of AMSEC runs, each with different value of X_i.
8. Tabulate or draw curves to display results of R/M/A/C/S vs X_i.

Steps 6, 7, and 8 can be automated in the future. In addition, the judgemental steps involved in Steps 4 and 5 can be laid out as procedures in many cases, and later automated if this appears desirable. The selection of increment size could, for example, be made adaptive depending on measured slope.

Multiple Variables

Changes can be introduced simultaneously in each of two or more input variables, and AMSEC will provide output estimates for R, M, A, C, S which

fully responds to the interdependence between these variables and from which the joint sensitivity can be determined. The procedural steps involved are analagous to those for the single variable. Computer runs are made for sequential steps in the first variable, X, which holding the second variable Y fixed of y; the process is then repeated for $y = y_2, y_3 \ldots y_n$. Again, at present these procedures which form a part of the AMSEC executive routine, are manually applied.

The process may be extended to three or more variables, where the third is run against each combination of the first two, etc. It is obvious that as the number of variables is increased, the number of computer iterations to carry out a multivariate sensitivity analysis increases combinatorially. The efficiency can be improved by:

a. Analyzing the variables in order of decreasing impact on RMACS.

b. Limitation of range of interest in each variable.

c. Keeping incremental steps as large as possible for each variable.

<u>Search for Optimality</u>

A special form of sensitivity analysis is the search for that value of the independent variable--or the combination of values for two or more independent variables--which will provide the "best" overall system configuration, as reflected in the R/M/A/C/S objective criterion. The above procedures will provide a rough location of the optimum, the accuracy depending upon the increment used. Alternative procedures, which can be readily adapted to computer programming, will provide a more precise location of the optimum point.

The first procedure simply extends the sensitivity analysis procedures:

1. Carry out single (multiple) variable sensitivity analysis as described.
2. From resultant sequence of values of objective function F(X) select two values of X which bound the minimum.
3. Reduce size of increment and repeat sensitivity analysis over the restricted range of X.

An alternative procedure can be carried out independent of the sensitivity analysis.

This process can best be illustrated for the case of a single variable and a unimodal objective function to be minimized (or maximized), such as that shown in Figure III.1. Basically the search for optimality amounts to the following procedure for a single variable:

1. Select as starting point X = A, where A can be 0 (or any value to the left of the optimum).
2. Evaluate objective Y = F(A).
3. Evaluate F $(A + \Delta X)$ where ΔX is a small positive increment.

3a. Calculate difference F $(A + \Delta X) - F(A) = D_A$.

4. Select a second point X = B.
5. Evaluate objective Y = F(B).
6. Evaluate $F(B + \Delta X)$.

6a. Calculate the difference $F(B + \Delta X) - F(B) = D_B$).

7. If D changes sign between A and B select a third point C midway between A and B.

7a. Calculate difference D_C near X = C.

7b. Determine pair AC or BC between which D changes sign.

7c. Select fourth point D interior to pair determined in 7b.

7d. Continue until D at selected point is within pre-selected proximity to D = 0.

7e. Select value of objective at final point as optimal.

8. If D does not change sign between A and B, select a third point C' exterior to A, B.
9. Evaluate D near X = C'.
10. If D does not change sign, continue Step 8,9
11. If D does change sign, repeat Steps 6,7

A typical sequence of steps following the procedures is shown in Figure III.2.

The multivariate equivalent of this process follows an analogous logic. The starting point represents a point on a multi-dimensional surface, represented by variables X_1, X_2,...X_n. The objective function $Y = F(X_1, X_2 ... X_n)$ is at an optimal value when all partial derivatives are zero. An iterative search proceeds as follows:

1. Select as starting point $X_1 = A$, where A is to left of optimum, and X_2, $X_3 ... X_n$ are all at nominal values.
2. Conduct single variable search for optimal $X_1 = X^*_1$ as above.
3. Enter X^*_1 as new nominal value of X_1.
4. Repeat Steps 1, 2 with other variables to locate X^*_2, X^*_3, etc. The point $(X_1^*, X_2^* ... X_n^*)$ is a quasi-optimum. However, since the X_i variables are interdependent, changes (e.g.) in nominal values of X_2, $X_3 ... X_n$ will change the location of optimal X_1. Therefore,
5. Repeat Steps 1-4 until the change produced in $Y = F(X_1 ... X_n)$ is within preselected bounds. The new multi-dimensional point X_1^{**}, $X_2^{**} ... X_n^{**}$ represents the optimal operating point.

TREATMENT OF PLANNING PROBLEMS

For many of the problems described in the following pages of this Section, the procedures have been automated, and the relevant computer programs are incorporated directly or by reference. For other problems the process is semi-automatic--i.e., some steps are computerized, others manual.

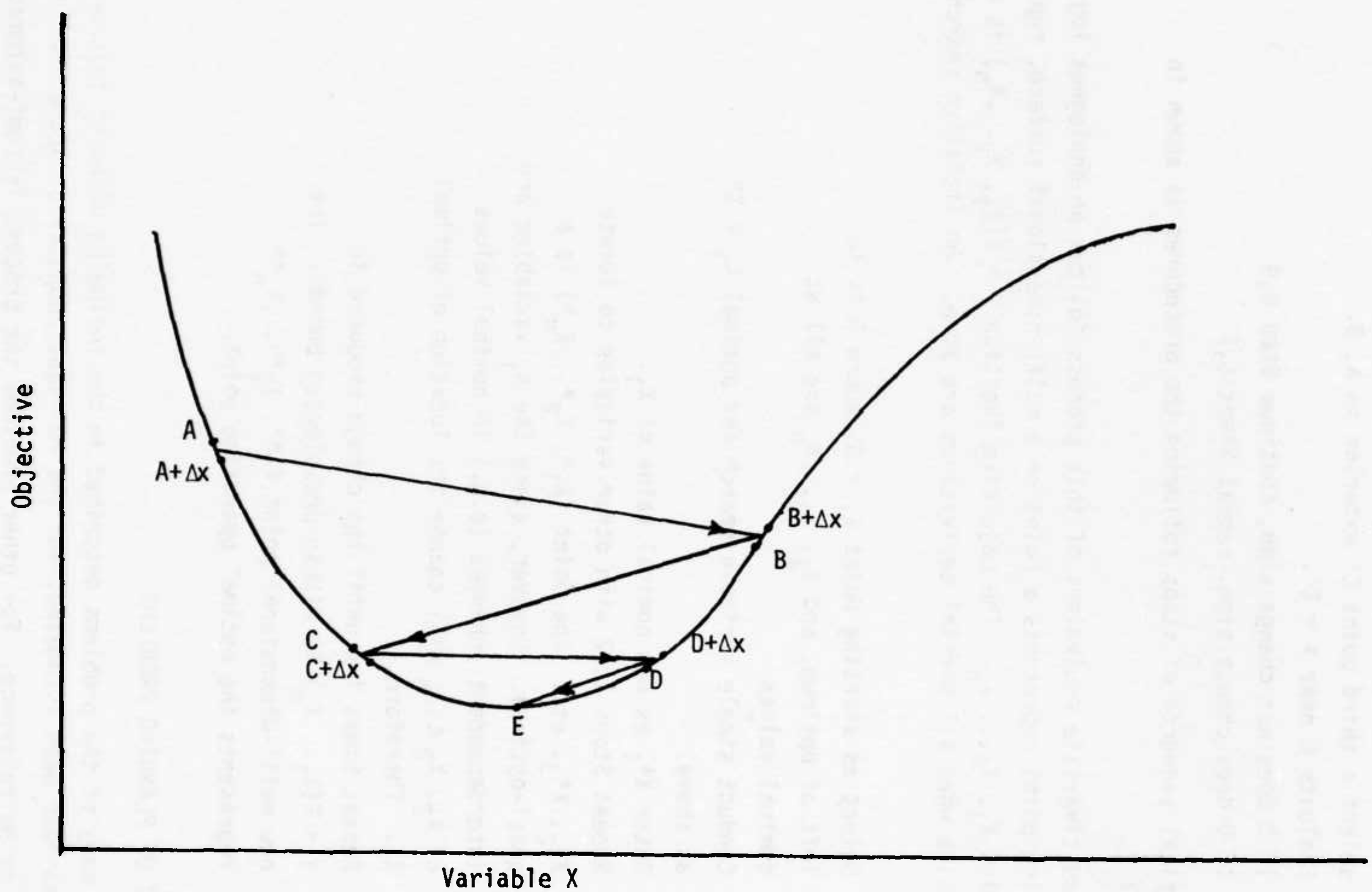

FIGURE III:2. ILLUSTRATION OF PROCEDURE FOR LOCATING OPTIMAL VALUE OF SINGLE VARIABLE

Finally, some problems are identified which have not yet been completely solved. These problems are important to the management and control of a development program, and are in principle solveable through the AMSEC formalism, but some further extension of the analytic base is required. The problems are introduced to give the reader a sense of the broad range of problems which can be addressed, and to show the place of each in the total integrated network of decision/evaluation/control.

SECTION 3
CHAPTER 1
CONCEPT STAGE

INTRODUCTION

At the concept stage in the development of a complex system, the major interests of management are in firming up the operational, performance, and cost requirements for the system, translating those requirements into functions, and the functions into general engineering techniques through which they can be implemented. The purpose is not so much to make a firm, definitive parameterization of the system, but rather to establish bounds, define the limits of feasible approaches to the problem and, in general define an "envelope" of parameters within which the system design, operation and support must lie. The particular train of decisions management makes in bounding the problem parametrically may have irreversible consequences which bear on RMA and cost, over the projected life cycle of the system. Consequently viewed in this light, some decisions are obviously of greater importance than others.

The application of AMSEC during the concept stage is directed toward providing management with a quantitative basis on which to assess his alternatives. This Chapter describes several problems which are typical, and shows how AMSEC can be used in their solution.

DEFINITION OF SYSTEM GOALS

Problem Description

The earliest statement of requirements for a system is likely to be in terms of the performance characteristics, P, which are desired (e.g., lift, thrust, carrying capacity) and the budget, B, available for its development. Both of these statements will be tentative at first, and the user will often settle for less performance if the cost of achieving it is "too-high", or he might ask for even higher performance if later development shows it can be achieved at a reasonable price.

At this stage the design region open to the developer is that shown in Figure III.3. Any combination of P and B that falls within the ruled area is satisfactory, and there is probably some room for negotiation, as indicated by the shaded area.

As conceptual thinking progresses, both P and B must be broken down into their major elements and goals established for these elements. For example, the concept of performance of an engine may involve several subsidiary concepts, e.g.,

a. Thrust--minimum acceptable

b. Missions and plans for use for the engine:

   1. Duration
   2. Criticality
   3. Frequency

c. Reliability for missions--minimum acceptable

d. Readiness for missions--minimum acceptable

Similarly the cost concept can be subdivided into:

a. Development cost--maximum acceptable

b. Operating cost--maximum acceptable

c. Support cost--maximum acceptable

d. Total cost (a+b+c)--maximum acceptable.

In general, both sets of parameters are interdependent. For example, if the thrust requirement is reduced, the development cost can be reduced, and the reliability can be maintained with a reduced level of support cost; similarly, a required reliability goal can be attained either by increasing the development

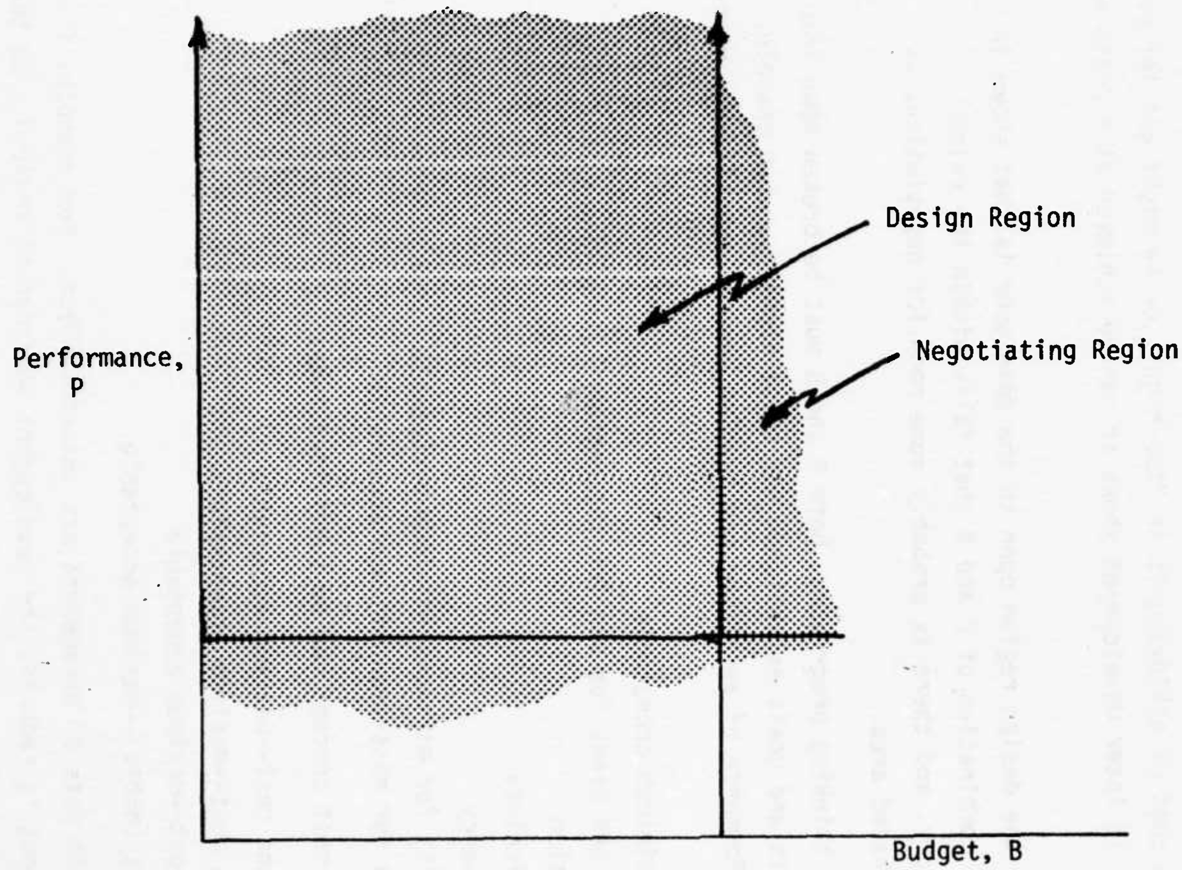

FIGURE III.3. EARLIEST REPRESENTATION OF ALLOWABLE DESIGN REGION

dollars to buy a larger MTBF, or by increasing the support budget to provide more frequent preventive renewal/maintenance. If the reliability goal is set too high, the costs to achieve it may be unacceptable, and the user must settle for lower reliability or he may reduce his mission requirements. The simple P-B design region thus can be subdivided into a multidimensional design envelope.

At this point the application of AMSEC can be used to focus management attention on the interrelations and trade-offs involved in formalizing the system requirements. Several examples are considered:

A. Setting Reliability Goals

Fixed Design

Establishing a reliability goal for a component (or for a system) has several cost consequences, which may include any or all of the following:

a. Cost of R&D and testing to improve life characteristics, C_1 (by failure mode, if desired)
b. Cost of enhanced support to reduce average age of component(s) used in a mission, C_2
c. Cost of in-use failure of component(s)(by mode) including loss of life, lost mission, crashes, etc., C_3
d. Cost of additional systems to meet mission force-level requirements, C_4.

Assuming for the moment that the design remains fixed (i.e., there is no R&D effort to change the life characteristics of the components so that C_1 is 0), the relations for C_2 , C_3, and C_4 above can be determined by AMSEC.

1. Enter nominal values (see Section I) for all parameters into AMSEC, including current best estimates for μ and $P(\mu/2)$.
2. Change value for TBO, and conduct sensitivity analysis of R and life cycle support cost, C_2 vs. TBO.
3. Plot corresponding pairs of R, C values to obtain desired C_2 vs. R plot for initial design.
4. From each of the j AMSEC iterations in Step 2, record R and corresponding value of expected number of mission failures for the i^{th} component(s), E_i. (by mode if desired).

5. Multiply each E_i by $K_{i,m}$ the expected cost of a failure of the i^{th} component in the m^{th} mode during a mission. Sum over i for all components considered, to obtain $C_3 = \sum_i C_i$ for each of the j iterations.
6. Plot sequence of values (for each iteration) of E_i K_i vs. R to obtain curve C_3 vs. R for initial design.
7. Multiply the assumed value of R for each iteration by N(1-R)P/R to obtain the expected cost of added float, C_4, where N is the number of fleet units required to survive a mission, and P is the cost of a unit.
8. Plot C_4 vs. R.

The general form of these curves is as illustrated in Figure III.4(a).

Increased MTBF

Now suppose that design changes are introduced which increase the acquisition cost by an amount from A to A + ΔA. The estimate of added cost would normally be obtained from the contractor. Suppose that with this cost, the life distribution can be improved by increasing μ by amount $\Delta\mu$, with $P(\mu/2)$ remaining unchanged. The AMSEC procedures to obtain C vs. R above are now repeated, replacing μ by $(\mu+\Delta\mu)$. The increase in MTBF will be found to lower the support cost curve--that is, a given R goal can now be realized at reduced support cost. The curves representing C_2 vs. R and C_3 vs. R will remain the same, since they depend only on R. The resultant situation is shown in Figure III.4(b), with the total cost curve from Figure III.4(a) superimposed for comparison.

It will be noted that the optimal management decision, based on the illustration shown, is to proceed with the new design, tailor the maintenance plan to match it, and select the corresponding R goal. This will lead to a least-total-cost configuration, where the cost of unreliability is contained in the cost measure.

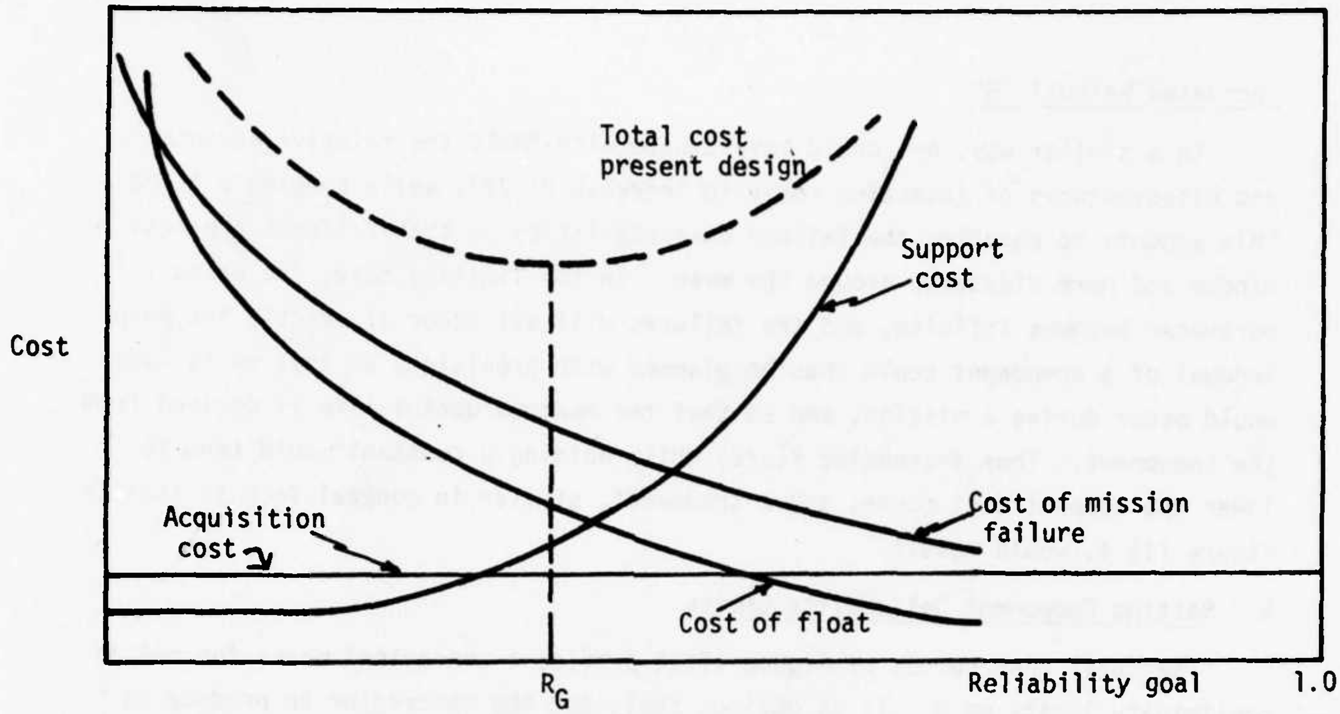

FIGURE III.4(a). COST CONSEQUENCES OF ESTABLISHING R GOAL, PRESENT DESIGN

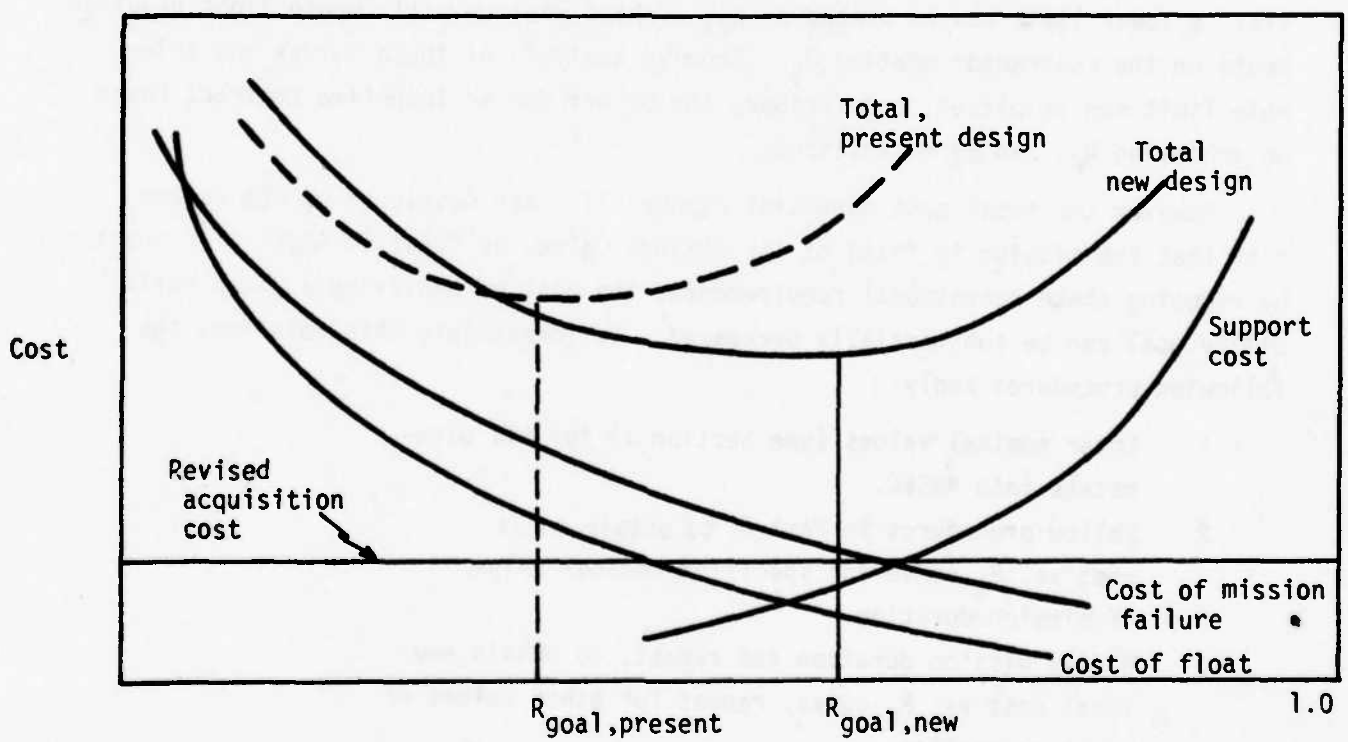

FIGURE III.4(b). COST CONSEQUENCES OF ESTABLISHING R GOAL, NEW DESIGN

Increased Weibull "B"

In a similar way, one could investigate with AMSEC the relative advantages and disadvantages of investing money to increase $P(\mu/2)$, while keeping μ fixed. This amounts to changing the failure characteristics so that failures are less random and more clustered around the mean. In the limiting case, the Weibull "B" parameter becomes infinite, and the failures will all occur at exactly the mean. Renewal of a component could thus be planned with precision, so that no failures would occur during a mission, and so that the maximum useful life is derived from the component. Thus increasing $P(\mu/2)$ while holding μ constant would tend to lower the support cost curve, and a trade-off, similar in general form to that in Figure III.4, would result.

B. Setting Component Reliability Limits

The total cost curves of Figure III.4 provide a convenient means for setting preliminary limits on R. It is obvious that, for the contractor to produce an equipment which falls below R, a cost is incurred, e.g., the cost of lost missions and/or additional float required. If the total cost response to R_G is relatively flat, a lower limit can be placed on R_G; a sharp minimum will impose tight requirements on the contractor meeting R_G. From an analysis of these curves the tolerable limit can be placed, and further, the payoff for an incentive contract based on achieving R_G, can be established.

However the total cost curves of Figure III.4 are developed on the assumption that the mission is fixed at its nominal value, as input to AMSEC. In practice, by reducing these operational requirements, the cost of achieving a given reliability goal can be substantially decreased. To investigate this relation, the following procedures apply:

1. Enter nominal values (see Section I) for all parameters into AMSEC.
2. Follow procedures in Part A to obtain total cost vs. R_G curve for specified nominal value of mission duration.
3. Modify mission duration and repeat, to obtain new total cost vs. R_G curve, repeat for other values of mission duration.

4. Display in graphical form (see Figure III.5) for illustrative diagram) the sequence of minimum cost values taken from the iterations obtained from Steps 1-3. Identify each with corresponding value of R_G as shown in Figure III.5.

The tactical cost of reducing the mission requirement, in terms of inability to perform is difficult to quantify. It is essentially a matter of judgment. However, a display of the form shown in Figure III.5 provides a basis for dialogue on the matter. It presents the interaction between design, support and operational tactics decisions. For example by reducing mission time from the nominal value (t_o) to a value t_1 will result in a cost savings $C' = C(R_{G,o}) - C(R_1)$. The dialogue between the development PM and TRADOC then centers around the question of whether the improved tactical capability represented by the longer mission time is "worth" the cost C'.

C. Setting Maintenance/Maintainability Goals

The establishment of M/M goals can be viewed as an analogous problem to setting R goals, as described in A above.

There are cost consequences involved in establishing the M/M goal. For convenience, we shall focus on the single parameter τ, describing the time to remove/replace the component; the costs include:

C_1= Cost of R&D to redesign the component, e.g., improve accessibility, adapt it to special tools, modify packaging, etc.

C_2= Cost of enhanced support to speed the replacement process, e.g., more maintainers, better training, better tools, automation

C_3= Cost of unreadiness when needed for mission, e.g., any special impact on the mission, such as cost of delay if any, or abort

C_4= Cost of additional systems to meet mission force-level requirements

The procedures for analysis follow quite closely to those given for R above; assuming no R&D, we hold C_1 fixed. Then,

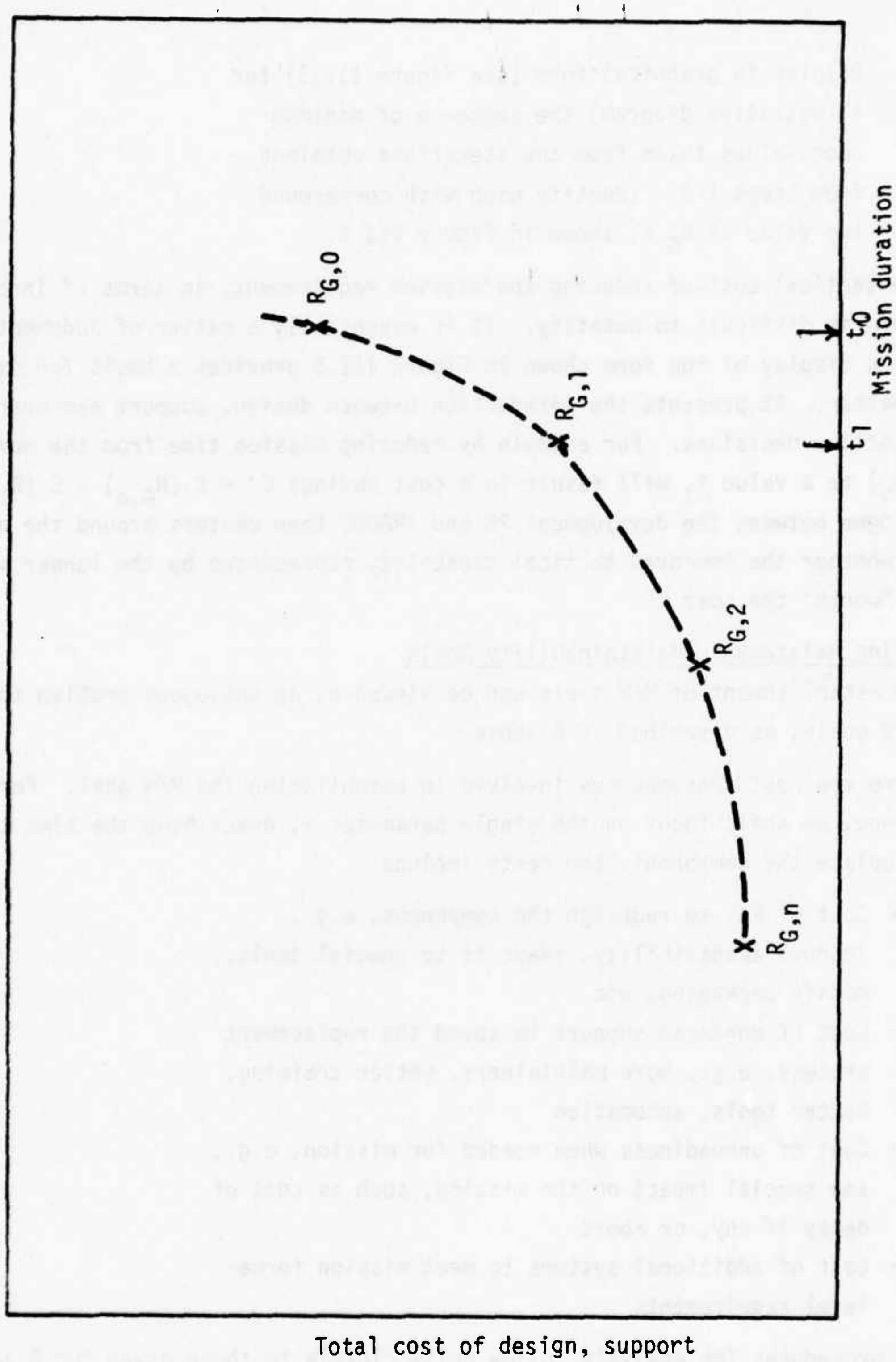

FIGURE III.5. EFFECT OF TACTICAL REQUIREMENT ON PREFERRED RELIABILITY GOAL

1. Enter nominal values (see Section I) for all parameters into AMSEC.
2. Change value for τ and conduct a sensitivity analysis of life cycle support cost C_2 vs. τ.
3. Plot values of C_2 vs. τ for initial design (C_1)
4. For each of j AMSEC iterations above, record τ and the corresponding value of availability for the i^{th} component, A_i.
5. Multiply the probability of the operation being unready due to the i^{th} component, $(1-A_i)$ by K_i, the expected cost of that component not being ready. Sum over i for all components considered, to obtain $C_3 = \sum_i (1-A_i) K_i$ for each iteration.
6. Plot sequence of $(1-A_i) K_i$ vs. τ_i for each iteration to obtain C_3 vs. τ for initial design.
7. For each AMSEC iteration of τ, select corresponding A_i for each mission-sensitive component. Multiply to obtain $A_j = \Pi A_i$, the probability that the system is available for the mission, assuming that particular value of τ.
8. For each of the A_j corresponding to the j iterations of τ, calculate $N(1-A_j)\,P$, where P is the cost of a single system; this gives the expected cost C_4 of added float to provide for a full consist of N systems required for the mission.

SELECTION OF FUNCTIONAL IMPLEMENTATION METHODS

Problem Description

The initial formulation of the performance requirements for a system specify capability, i.e., tasks to be carried out. From this stage, the first engineering task to be accomplished is the specification of functions which must be carried out to provide that capability. These functions may be of the form, e.g.,

- Provide a lift capability of X pounds
- Provide a cargo volume capacity of y cubic feet
- Provide an air speed of z knots,
- Etc.

In many cases, a given function can be implemented in any one of several ways. For example aircraft speed could be provided alternatively by rotor action or by jet engine. At the concept stage a preliminary assessment of these alternatives is required, and an engineering judgment of the preferred mode is established, which will hold unless and until further design/test information changes the verdict.

AMSEC can be used to provide quantitative insight to management in making this decision. An example of this form of application is provided below.

Analysis Procedure

As an example of the use of AMSEC in this decision area, we shall consider the function of providing aircraft thrust, which can be accomplished (a) through the use of rotors, or (b) through the use of jet engines.

1. Describe alternative configurations which could be used, for both prop and jet engines, for the range of thrust which is required. Alternative configurations should be considered, i.e.,
   a. Single engine to develop required thrust
   b. Multiple engines to develop required thrust.
2. For each alternative determine state-of-the-art for component life characteristics, replacement/repair time and effort, and acquisition cost. If all alternatives are "off-the-shelf" this data should be well

documented; if not, it may be obtained by extrapolation from generically related systems, or from engineering analysis and judgment (see Section I for further discussion of input data).

3. Conduct point-analysis for first of alternative configurations.
4. Conduct sensitivity analysis of first alternative with respect to TBO and time-to-replace, and select best operating point (refer to p. 104 for discussion). Evaluate R, A, C and S at this point.
5. Establish a system for rating the weight of R, A, C and S to develop a single rating index for each configuration. This step serves to structure engineering judgment by setting up a formal scoring system. An example of such a system is shown in Figure III.6. This format provides for placing a rating on each of several ranges of values for each measure; by excluding (with an "X") certain ranges of a measure, the format addresses the relative importance between different measures (e.g., an availability in the range .95 to 1.00 is considered to have the same importance as a reliability of .75 to .85. Both have a rating of 3.0 in Figure III.6). The total score for each alternative may be taken as simply the arithmetic sum of the ratings as shown; or one of the alternatives could be excluded if any rating drops below (e.g.,) 1, for any measure, etc.
6. Repeat Steps 3, 4, and 5 for other alternatives.
7. Select best of stated alternatives.

	Rating Values						Score for Alternatives			
Score →	5	4	3	2	1	0	A	B	C	D
R	95-100	85-95	75-85	60-75	50-60	<50	5	5	4	3
A	X	X	95-100	80-95	60-80	<60	2	3	3	0
C	$ 10K	10-15K	15-18K	18-20	20-22	>22	3	3	2	5
S	X	X	X	X	≤ 3	≥ 4	1	1	0	0
Total Score							11	12	9	8
Relative Rating (Max possible score = 14)							.78	.85	.64	.57

Select Option B

Selected Option

FIGURE III.6. ILLUSTRATIVE SCORING WEIGHTS FOR AMSEC RATINGS

DIALOGUE BETWEEN USER AND DEVELOPER

Problem Description

As indicated in an earlier section, during the concept stage both the user's needs and the developers capability have been expressed tentatively. If either finds that what he proposes poses a major obstacle to the other, there should be a dialogue between the two with the intention of resolving the issue. The problem is that the dialogue either never takes place, and the developer goes ahead with the design of an exhorbitantly expensive system to meet an overstated need; or the dialogue takes place between two different disciplines, e.g., the technician and engineer--who didn't have a common "language" for addressing the problems.

AMSEC can provide the means for such a dialogue, since it translates the designers engineering proposals into the tactical consequences which they would bring about for the user.

The dialogue begins when the analyst, acting as "translator" puts the first tentative system parameters into AMSEC, and obtains estimates of field behavior in R, M, A, C and S which may or may not meet the originally stated objectives. If they do not, either the design/support complex must be changed or the field objectives must be reduced. To determine the most cost-effective compromise requires both the user and developer to state, in quantitative terms, the reason for their position and the cost--in dollars, safety, or other--of deviating from that position. That is, they must participate in a sensitivity analysis.

One example involving a TRADOC-developer dialogue was described on p. 114 under "Setting Component Reliability Limits". Another common example is the following.

Suppose the user has specified the need for an aircraft that will provide a 500 knot speed, with 99% reliability of completing a 1,000 mile mission. The developer finds that existing experience with engines of the necessary thrust shows that they are only 90% reliable over 1,000 miles. The decision to be faced: should a development program be undertaken to meet the specified reliability objectives, or should the objectives be modified?

Analysis Procedure

1. Insert nominal values of input parameters into AMSEC and obtain preliminary values of R, C.
2. Carry out sensitivity analysis of R with respect to mission length (see Figure III.7). The options for reconciling user needs with development capability are:
   a. Reduce reliability target from R_2 to R_1
   b. Reduce mission length from L_1 to L_2
   c. Apply R&D to drive R_1 to R_2 for current target mission, by changing MTBF and/or $P(\mu/2)$
   d. Modify support plan to improve reliability
   e. A combination of (a), (b), (c), or (d).

The cost of (a) and (b) or a combination of (a), (b), in terms of tactical capability must be assessed by TRADOC; the use of (d) as an option was described earlier. The cost of R&D to accomplish the required improvement in MTBF must be estimated by the developer. Ultimately, the user must decide which cost(s) govern.

3. Organize options in order of increasing cost to reconcile user/developer.
4. Select least-cost option.
5. The use of mixed options--i.e., combining two or more of the options, can also be evaluated if cost data of the necessary granularity are available. This would be done stepwise, as follows:
   a. Select mission length at L_{xo} where $L_2 < L_{xo} < L_1$; read off R_x from sensitivity run, Step 2.
   b. Determine cost of reduced mission length $L_1 \rightarrow L_{xo}$
   c. Determine cost of reducing reliability $R_2 \rightarrow R_{xo}$
   d. Add (b) + (c) and assess total against results from Step 3
   e. Select least cost option
   f. Iterate (5) as desired for other L_x.

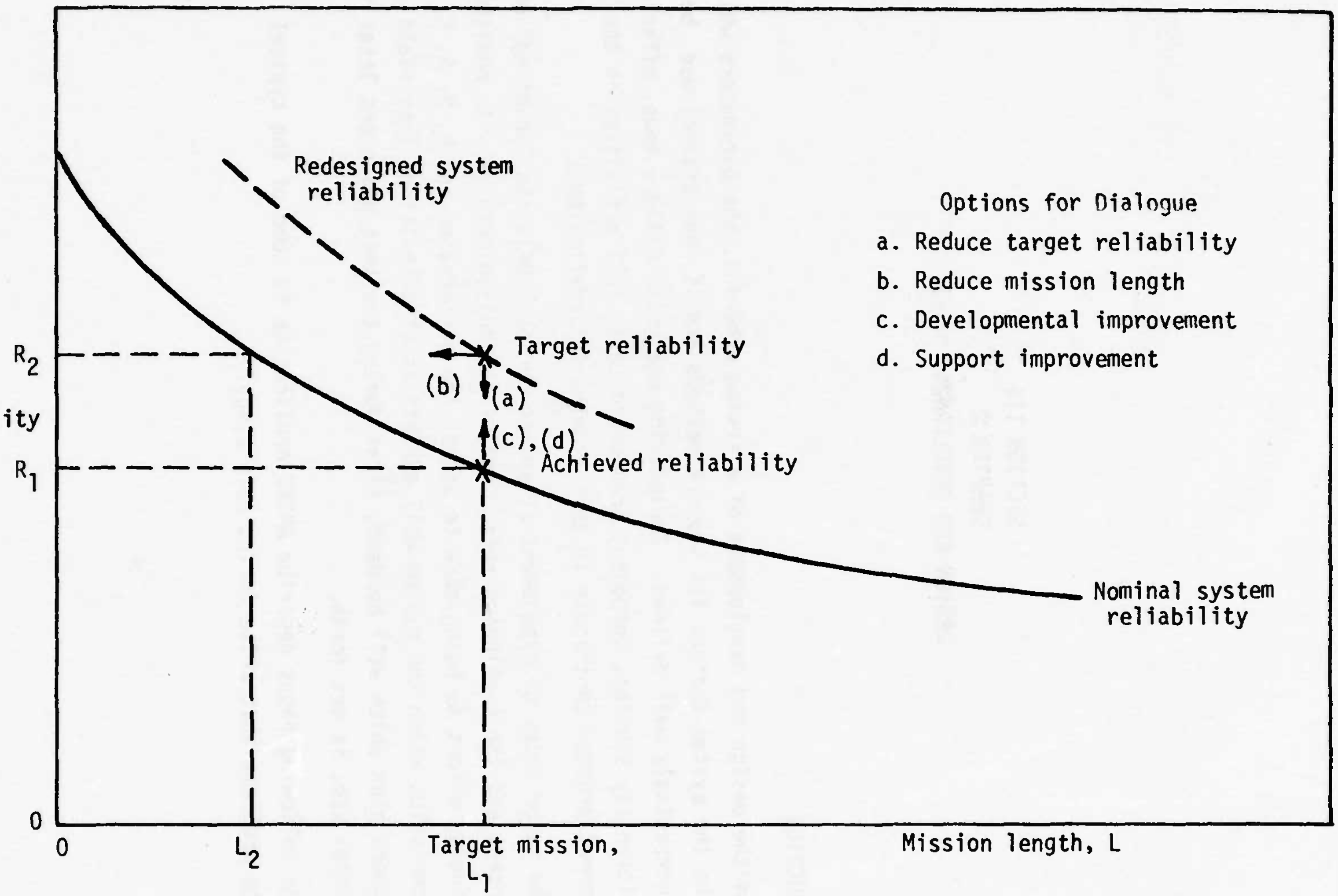

FIGURE III.7. ILLUSTRATIVE SENSITIVITY OF R TO CHANGES IN LENGTH OF MISSION

SECTION III
CHAPTER 2
DESIGN AND DEVELOPMENT STAGE

INTRODUCTION

As the design and development of a system proceeds, the parameters which describe the system design, its support methods and its operational use become increasingly well defined. Engineering analysis, failure mode, effects, and criticality studies, component breadboard tests--all activities in the development process contribute to this growing information base.

The major focus of management attention during D/D is the "proofing" of the concept and the continuing refinement of the design details. In addition, a continuing effort is being made to assess the performance and R, M, A, C, S characteristics which the system will exhibit as it transitions into field use. The support plan which will be used, first during the test phase and later in operational use, is set forth.

The following pages describe AMSEC application to some of the typical planning problems that arise during this stage.

PREDICTION OF IN-USE R, M, A, C, S

Problem Description

Throughout the development process it is important for management to have continually updated estimates of the R, M, A, C, S characteristics which the system will have when it is completed, and to examine sensitivity of these measures to the critical parameters in order to support timely decisions. Periodic assessments of a formal nature are required in response to (e.g.,) MIL-STD 702-8; other interim assessments may be required on an ad hoc basis.

Analysis Procedure

The procedures for developing a point estimate of RMACS were set forth in Section II of this Handbook, and the procedures for a sensitivity analysis were described at the beginning of Section III. The same steps are followed here, but the input parameters are more sharply defined; some parameters which could freely vary during concept become frozen as development proceeds, and the mix of parameters for which a sensitivity analysis is necessary, will change:

1. Insert input parameters into AMSEC.
2. Develop system RMACS point estimates.
3. Develop system RMACS sensitivity studies as required by management.
4. Prepare formal evaluation report.

An example of AMSEC point estimate of component and system RMACS is provided in Appendix D.

Computer Programming Summary

The insertion of the results of an evaluation into the textual format of a prescribed report such as MIL STD 702-8 is a process which can be readily automated. This capability can be added as an AMSEC option and the computer will print out the entire MIL STD report, or such parts of it as are desired.

ASSESSMENT OF DESIGN ALTERNATIVES

Problem Description

The designer is often faced with the problem of selecting between two or more different design techniques to solve a system problem. Usually each will have its own peculiar RMAC properties over the projected life of the system, and AMSEC can be used to help determine and display these properties for management review. Examples of such decisions, at the level of engineering detail which must be addressed, include:

- Achievement of MTBF goal for a component by "beefing up" the design, vs. the use of redundant units.
- Designing a unit for removal and repair vs. design for throwaway.
- Physical packaging (or conceptual "packaging") of two or more units together for removal/repair vs. retaining separate removal/repair capability.
- Use of "off-the-shelf" items vs. development of new designs; extent of standardization in selection of components.
- Selection of item source from competing vendors.
- Trade-offs between R and safety; between false alarms and false clears.
- Use of monitoring circuits to measure condition as an aid to maintenance planning.

The following pages describe the approach to be used in applying AMSEC to problems of this nature.

Analysis Procedure

In each case, the basic analysis procedure is:

a. To structure the alternative actions so that the AMSEC input parameters which are specific to the two alternatives can be identified, and their value determined for each case.

b. To carry out AMSEC runs for each alternative,[12] and

c. To compare, and select the preferred action. Some specific examples will illustrate this process.

A. Use of Redundancy vs. Redesign of the Unit

1. Identify those input parameters to AMSEC which are sensitive to this decision. They are:
   a. The material cost of the component.
   b. The cost of labor involved in removal/ replacement actions
   c. The life characteristics of the component, μ and $P(\mu/2)$
   d. The number of units employed, and number required for success.

Other parameters may be effected (e.g., the probability of induced failure) but those shown are sufficient to illustrate the analysis procedure.

2. Determine the input parameter values for each alternative under consideration. In this case a table of parameter values might have the appearance shown:

Input Parameter	New Design Concept	Original Design Concept (redundant)
No. of components	1	4
No. required for operation	1	2
Material cost/unit	\$10K	\$2K
Repair time/unit	2.0 hrs	1.5 hrs
Labor cost/action	\$50	\$40
Mean life hours	1500	500
Half life, $P(\mu/2)$	.8	.7
All other parameters	same	same

[12] Several iterations of AMSEC sensitivity may be required in each case to obtain the most cost-effective combination of the other (non-specific) parameters which are under management control (e.g., the TBO for preventive maintenance.)

3. Enter all parameters into AMSEC to obtain system outputs.
4. Tabulate and compare AMSEC outputs. For example, a table of outputs may have the appearance shown:

Output Measure	System with New Design Concept	System with Original Design Concept
Reliability	.95	.98
Availability	.99	.99
Life cycle support cost	$20/hr	$25/hr
Spares required	1	1

5. Select preferred alternative. In this case, if the gain in going from .95 to .98 reliability is judged to be worth more than $5/hr, the use of redundancy would be selected.

B. Selection of Packaging Configuration

The decisions of how to subdivide and package within a system have important RMACS consequences.

Two or more components may be put together in such a way that they are maintained/removed/replaced together. When one fails, all are replaced; when one is preventively removed, all are preventively removed. This grouping, or "packaging" of components may involve a physical encapsulating into a single unit; or it may involve merely a procedural edict. In either case, the effect on scheduling of actions is the same.

1. Identify the alternative packaging configuration alternatives. For simplicity, assume they are as shown below:

Configuration 1   [Comp A] —— [Comp B]

Configuration 2   [Comp A | Comp B] = [Comp AB]

The new component AB, may be viewed as a single component having two independent modes of failure, i.e., A fails and/or B fails.

2. Identify the AMSEC input parameters which are sensitive to this decision. They include, for example:
   a. The material cost of A, B, and AB
   b. The cost of labor involved in remove/replace actions
   c. The life characteristics μ and P (μ/2) for A and B
   d. Repair time for A, B, and AB
3. Determine input parameter values for each alternative: A, B, and AB
4. Conduct point-value analysis of "system" A + B and "system" AB (the two configurations shown)
5. Conduct sensitivity analysis for both systems with respect to preventive removal period, τ, and obtain least cost operating point for assumed cost of mission failure.
6. Tabulate AMSEC outputs for the alternative configurations and compare.
7. Select preferred alternative.

Figure III.8 shows the result of an analysis carried out on the Army's Gama Goat to assess the desirability of considering each set of multiple components (i.e., "u" joints, ball joints, yokes, brake assemblies, and tie rods) as a single "package" for purposes of maintenance.

C. Selection Between Competing Vendors

This amounts to an assessment of the relative life support cost and effectiveness consequences which result from buying a component from either of two competing vendors. Several factors need to be distinguished for each version; these include:

a. Life characteristics μ and P (μ/2).
b. Component cost.
c. Estimated labor cost to remove/replace.
d. Estimated distribution of time to remove/replace.

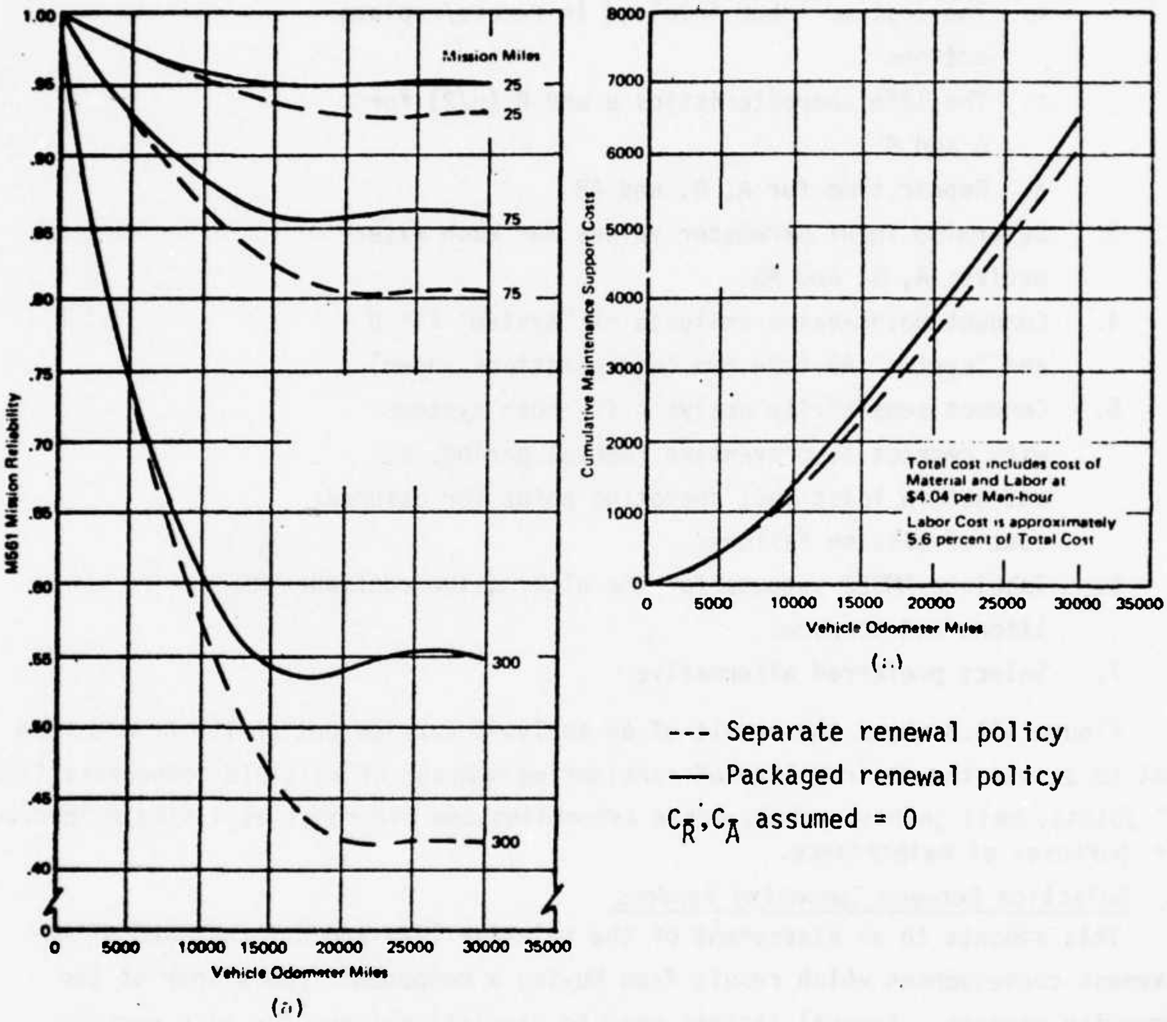

FIGURE III.8. COMPARATIVE EVALUATION OF RELIABILITY AND COST UNDER ALTERNATIVE PACKAGING CONCEPTS

The following procedures are followed in assessing the relative units which accrue to each option:

1. Collect estimates of values of pertinent parameters from competing contractors.
2. Review contractor documentation or conduct in-house tests to confirm parameter values.
3. Enter into AMSEC and obtain point estimates for each.
4. Conduct sensitivity analysis to determine minimum cost TBO in each case.
5. Prepare matrix of estimates of R, M, A, C and S for each option as determined in Step 4.
6. Select preferred vendor.

USE OF MONITORING AND ON-CONDITION MAINTENANCE TECHNIQUES

Problem Description

With equipment which tends to fail exponentially, there is no wearout exhibited and failure is essentially random. Under these conditions, monitoring is of no value. Where wearout is involved, either as a continuing factor or as a factor whose onset may be triggered by a random event, a monitoring procedure can often estimate the extent of the underlying degradation by measuring some observable performance parameter or physical feature. The removal time can then be selected so as to minimize total support cost. This is often a more precise, and consequently more cost-effective procedure, than so-called hard-time removal. Whether it should be used in preference to the hard-time-removal, or the repair-upon-failure options, depends on the characteristics of the specific component, and the monitoring techniques under consideration. Several factors are involved:

a. Life characteristics of component.
b. Accuracy of monitoring measure (error distribution) selected for component feature.
c. Measurement threshold assigned for removal.
d. Distribution of selected-feature measurement at time of component failure (or distribution of estimated remaining life when selected feature is at prescribed threshold).
e. Material cost of component.
f. Labor cost of remove/replace actions.
g. Capital cost of monitoring equipment.
h. Operating cost of monitoring equipment.

Of these characteristics, all but (c) are predetermined for purposes of this illustration. Item (c) can be varied to obtain a minimum cost monitoring procedure. Item (d) can be estimated from an engineering assessment of data on components returned for overhaul, such as the currently documented disassembly, inspection, and repair (DIR) reports.

Analysis Procedure

1. Calculate *effective* life characteristics of component. The actual life characteristics of the component, in terms of time to failure, will be modified by the existence of the monitoring procedure. What we wish to calculate is the distribution of times to removal, broken down by "mode," or reason for, such removal, where the modes are defined as:
   a. Failure of component, and
   b. Removal through monitoring policy.

The effective life characteristics can be determined analytically from the above factors (a), (b), (c), and (d). This analysis subroutine, and the necessary AMSEC programming, represents a fairly straightforward extension to existing AMSEC capability.

2. Enter all parameters into AMSEC and obtain point-estimates.
3. Conduct sensitivity analysis to optimize monitoring threshold for removal actions.
4. Enter original component failure distribution (without monitoring) into AMSEC and obtain point estimates.
5. Conduct sensitivity analysis to optimize TBO for hard-time removal actions.
6. Enter TBO = ∞ to evaluate the repair-upon-failure options.
7. Compare and select preferred option.

CHAPTER 3
TEST STAGE

INTRODUCTION

As the field test stage of the development program gets under way, most of the design decisions have been made. The system is being tried out in an actual use environment, although that may not be the same as the final environment in which the system will be used operationally. The major thrust of the test program is to see how the system responds in the real world, to translate that response into an updated appraisal of how it can be expected to behave in operational use, and to "fine-tune" any system design, support or use parameters which can still be adjusted.

The following pages describe AMSEC application to some of the planning problems that are typical of the test stage.

UPDATED ASSESSMENT/PROJECTION OF RMACS

Problem Description

Estimates of the RMACS characteristics of the system as displayed during the test stage are usually required contractually. Quite often acceptance of the system depends upon the field demonstration that adequate levels of reliability and availability have been reached through the development process, and that support cost has been held within specified limits.

The problem has two aspects:

a. The assessment under test conditions, and
b. The projection to specified operational use conditions.

The differences between the two operational environments lie in several factors:

a. The mission duration
b. Component utilization and stress
c. Operational failure criteria for components/systems
d. The maintenance plan
e. Skill levels, equipment, etc., available for maintenance, with consequential impact on repair times, diagnostic accuracy, etc.
f. Procedural rigor in following operational/maintenance schedules.

The test observations, coupled with D/D data from engineering, will provide best estimates of the equipment related inputs. By combining this information with the operational and support data, first for the test environment and then for the use environment, AMSEC can provide the corresponding assessments for the system and for its components.

Analysis Procedure

1. Collect parameter values applicable during test
2. Conduct AMSEC analysis to obtain point values of RMACS for test conditions

3. Modify use and support parameter values to describe anticipated operational use.
4. Conduct AMSEC analysis to obtain point values of RMACS for operational conditions.
5. Conduct sensitivity analyses with respect to e.g., component <u>TBO</u> interval to optimize operational projections.
6. Prepare formal reports as required.

SELECTION OF M STRATEGY

Problem Description

For a system whose design and operational use patterns are established, the cost effectiveness of the system can be improved by proper selection of preventive maintenance removal intervals for the components. For the moment we shall focus on hard-time renewal as the basic approach; the extension to condition-monitoring and on-condition maintenance is obvious in the context of the discussion in Chapter 2 preceeding.

From the overall system viewpoint the approach to determining optimal maintenance strategy involves three steps:

1. Determine the optimal renewal interval for each major/critical component.
2. Integration of analysis (1) to consider single vs. multiple renewal actions during a given maintenance repair downtime.
3. Determination of the optimal allocation of a limited maintenance budget between renewal schedules for different components.

AMSEC in its present form can provide solutions to (1) and (2). The allocation problem, Item (3) has been successfully solved by COBRO in a related area, and could be readily merged with AMSEC to further extend its capability.

Analysis Procedure

A. Optimal component renewal interval:
   1. Specify number of missions (ν) or time over which the M plan is to be evaluated for system use.
   2. Enter all design and operational use data for i^{th} component into AMSEC; enter nominal value of TBO interval, and enter estimate of mission failure cost ascribable to failure of the i^{th} component (in the m^{th} mode; if desired).
   3. Conduct sensitivity run with respect to TBO interval, τ, to obtain optimal value over the ν-mission period of use.
   4. Tabulate results by component, in order of increasing values of τ. Printout renewal labor man hours and calendar hours for each.

B. Single renewal vs. merged renewal:

The advantage in merging two (or more) preventive maintenance actions lies in two factors. First, if the components are located close together physically, the maintainer may be able to take advantage of a single equipment disassembly action to conduct both actions, and thus save time and labor. Second, if the two distinct TBO optima are located close together in time, the maintainer may accomplish both during a single system down-time, and thus save system availability. Candidate groupings of components should be tested from both viewpoints.

1. Enter tabulation of Step A.3 above to identify and code those groupings of n components where a single teardown would provide maintenance acess to all.
2. Select a subset X_i of these n components for evaluation, where merged renewal actions are deemed feasible from an engineering viewpoint.
3. Determine labor man-hours and calendar-hours for teardown and close-up actions, which are common to all X_i components.
4. Calculate labor man-hours and calendar-hours for multiple renewal of all X_i.
5. Conduct a sequence of AMSEC system evaluations using each subset combination X_i as a single merged unit.
6. Compare results of B.5 with those of A.2 and select preferred strategy.
7. Enter tabulation of Step A.3 above to identify and code those components which were not considered for single teardown but whose individual TBO optima occur within a short enough time interval t_i so that the desirability of combined actions should be tested.
8. Conduct an AMSEC system evaluation using those components whose individual optima lie within $\pm t_i$ as a single merged unit.

9. Conduct sensitivity analysis with respect to t, and select minimum cost. Note that for t=0, the results will coincide with A.2 above.
10. Aggregate the results of A.2, B.6, and B.9 to specify the minimum cost maintenance strategy (corresponding to assumed mission failure cost penalties).

C. Allocation of Maintenance Budget

For a given (i^{th}) component, the assignment of a hard-time renewal interval has an impact on both its reliability/availability and on its support cost. In particular if the interval is reduced, the average age of components in field use is reduced. For equipment with wearout characteristics, this means mission reliability will increase. The reduced TBO, however, will cause an increase in replacements and hence in support cost, assuming that the cost of replacement upon failure is no greater than the cost of replacement prior to failure. If more money is invested in terms of additional support cost (decreased TBO), reliability can be improved. AMSEC can be used to develop a "reliability return curve" of the form shown in Figure III.11a for each component. This curve displays graphically the improvement in reliability brought about by a specified increase in support cost.

Now if a limited support budget is available, that budget must be allocated between contending candidate components. The situation is illustrated for two components in Figure III.11b. Each curve shows the gain which would be realized for the corresponding component, if the specified budget were spent on that component exclusively.

Since the reliability of the AB system is given by

$$R_{AB} = R_A \times R_B$$

it is obvious that the planning problem is to so allocate the total available resources between component A and component B that the product $R_A \times R_B$ is maximized. A body of mathematics has been developed and applied to this specific allocation problem, so that the most efficient expenditure of resources is accomplished. Procedures for budget allocation are:

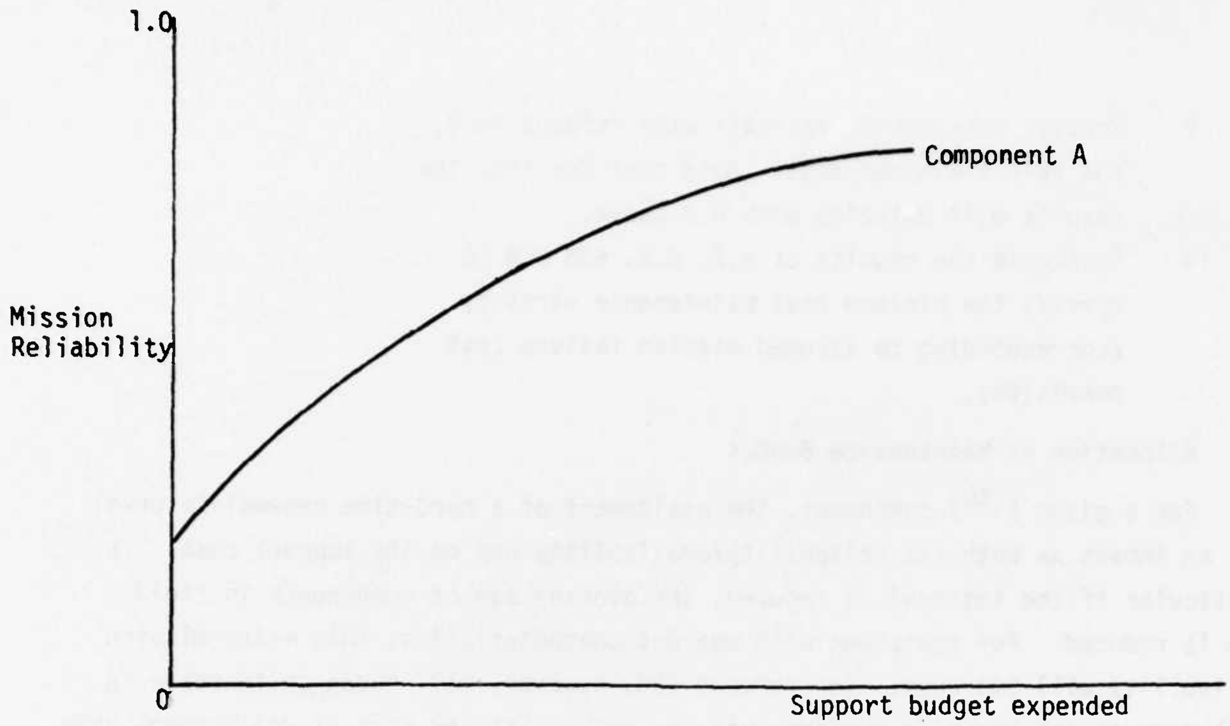

FIGURE III.11(a). TYPICAL RELIABILITY RETURN CURVE

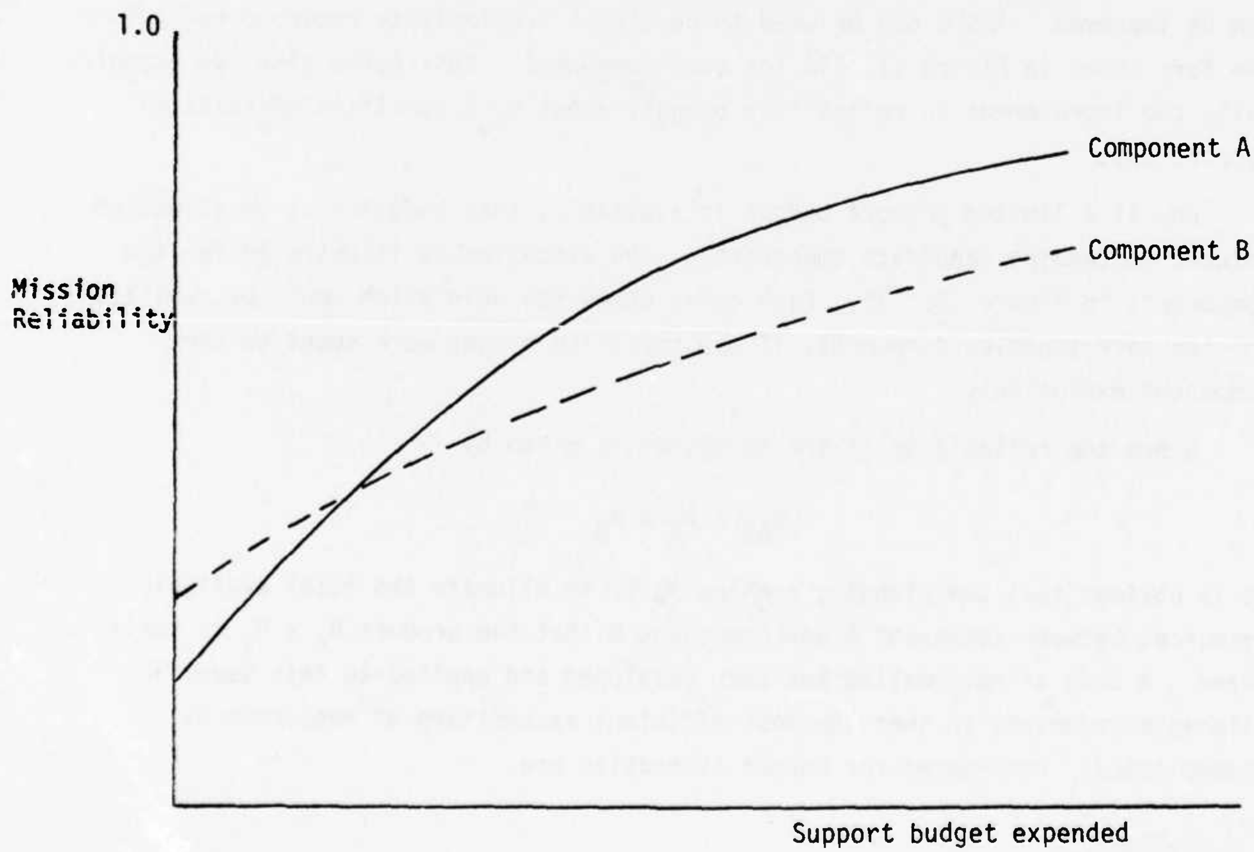

FIGURE III.11(b). MULTIPLE RETURN CURVES FOR BUDGET ALLOCATION

1. Enter all data for the i^{th} component into AMSEC.
2. Conduct sensitivity analysis of R and C to changes in τ.
3. Develop return curve by plotting corresponding pairs of values of R and C for each iteration.
4. Repeat for each of the n components making up the "system".
5. Specify a nominal budget Q_0.
6. Obtain optimal allocation of Q_0, using COBRO's Resource Allocation for System Planning (RASP) model as extension to AMSEC.

As a further step in the analysis it may be useful to repeat these steps for different values of Q, and thus investigate the RMAC consequences of having different limits set on support cost.

Illustrative Example

The AMSEC illustration in Appendix D provides an analysis of a problem of the general nature described in (A) above. The results obtained in Appendix D relevant to this problem are shown in Figure III.12.

CHAPTER 4
OPERATIONAL USE STAGE

INTRODUCTION

The introduction of the system into operational use provides management with the opportunity to calibrate the system in its actual end environment under specific mission conditions, to assess the accuracy of earlier RMACS and performance predictions, and to respond to any deviation from anticipated behavior with appropriate fixes.

The assessment of RMACS can now be based on the most realistic data yet available. In addition it is useful at this stage to broaden the assessment to incorporate total fleet capability, in terms of e.g., aggregate fire power available on a target, or number of mobile systems surviving a march time and distance.

Although many of the system parameters are frozen at the time when the system becomes operational, several important options are still open, and it is upon these that management attention will focus. These include:

- Tactical uses of system, e.g., mission duration, mission frequency, allowable downtime.
- Maintenance strategy details, e.g., component TBO refinement, level of repair designation.
- Engineering change proposals.

The following pages describe AMSEC application to several of these planning problems.

ASSESSMENT/PREDICTION OF IN-USE R, M, A, C, S

Problem Description

The added precision in input parameter estimates which can be achieved during operational use provides an opportunity for a periodically updated review of predicted RMACS, and a comparison against actual observed behavior. In addition, it permits an improved projection of the RMACS attributes in other environments than the current one, and for other combinations of missions.

Analysis Procedure

The procedures for developing a point estimate of RMACS were set forth in Section II of the Handbook, and the procedures for a sensitivity analysis were described at the beginning of Section III. The same steps are followed here, but the input parameters are more sharply defined; some parameters which could freely vary during concept or during D/D may now be frozen. As a result the mix of parameters for which a sensitivity analysis is necessary, will change. The basic procedure for the RMACS evaluation are:

1. Insert input parameters into AMSEC.
2. Develop system RMACS point estimates and sensitivity studies as required by management.
3. Prepare formal evaluation report.

An example of AMSEC point estimate of component and system RMACS is provided in Appendix D.

Computer Programming Summary

The insertion of the results of an evaluation into the textual format of a prescribed report such as MIL STD 702-8 is a process which can be readily automated. This capability can be added as an AMSEC option and the computer will print out the entire MIL STD report, or such parts of it as are desired.

SELECTION OF OPERATIONAL TACTICS

Problem Description

Operationally related parameters which are direct inputs to AMSEC include:

a. Mission duration
b. Mission frequency
c. Mission type (component utilization)
d. Cost of mission failure
e. Mission success criteria.

Other mission-related parameters enter AMSEC through a secondary path, by their influence on the previous AMSEC inputs. For example, a sequence of missions which exerts more stress on the system, by virtue of higher operating loads or a more harsh environment, will influence AMSEC through their effect on the component life characteristics, or through the need for longer repair/replace times, etc.

The ability of AMSEC to integrate the impact of operational parameters with that of design and support parameters provides an important means of dialogue between diverse disciplines during design and development (see Chapter 2). After the system is in operational use, the planning focus of AMSEC shifts to the planning of the mission load which is best suited to match the system. The trade-off is between RMACS efficiency and tactical requirements. To examine this trade-off quantitatively it is useful for Operations to specify the value which an advanced mission capability provides, in terms of items, a, b, c, d, and e above. Sensitivity analyses of RMACS against these parameters--singly or jointly--will then be used to examine trade-offs.

Analysis Procedure

1. Obtain measures of value for (a) increased mission duration and (b) increased mission frequency.
2. Enter parameter values into AMSEC.
3. Carry out sensitivity analysis of Cost (including cost of unreliability, i.e., mission failure) vs. changes in (a) mission duration and (b) mission frequency.
4. If the value expression in Step (1) has been obtained, obtain optimum values of (a) and (b).

Figure III.12 illustrates the kind of quantitative trade-off which might be expected.

5. If the value expression in Step (1) has not been obtained, draw up tables of mission duration vs. total cost, for specified values of mission frequency. Table III.1 shows the format of such Tables. These will be provided for qualitative review and judgment by management.

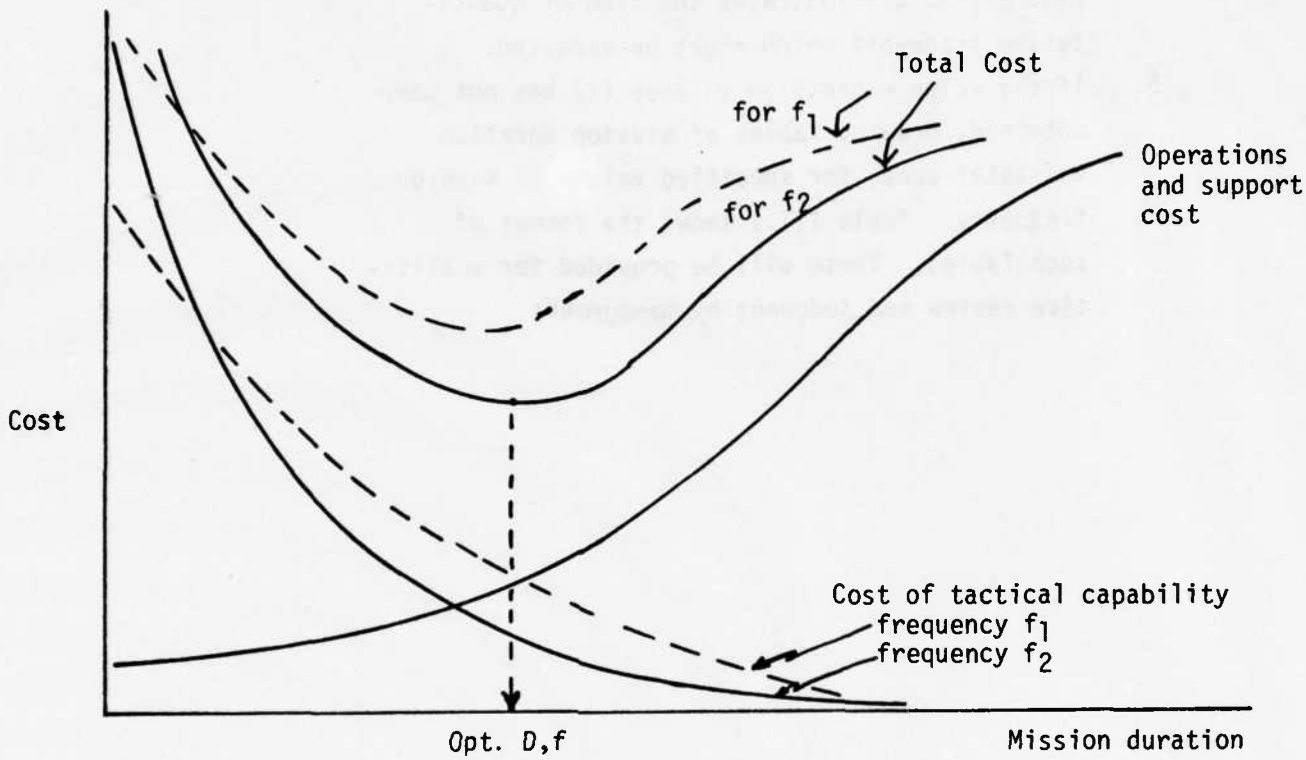

FIGURE III.12. EFFECT OF MISSION VARIABLES ON TOTAL COST

Frequency f_1		Frequency f_2		Fequency F_3	
Duration of mission	O/S Cost	Duration of mission	O/S Cost	Duration of mission	O/S Cost
D_1 D_2 . . . D_N	C_1 C_2 . . . C_N	Etc.	Etc.	Etc.	Etc.

TABLE III.1. RELATIONS BETWEEN MISSION VARIABLES AND SUPPORT COST

EVALUATION OF ENGINEERING CHANGE PROPOSALS

Problem Description

After a system has been released into operational use, experience may disclose weaknesses in individual components or subsystems which should be corrected. Engineering changes may be proposed to remedy the problem; to the extent that these changes may impact on R/M/A/C/S, AMSEC can be used to evaluate the alternatives.

The basic problem to be resolved is (e.g.,) whether the improvement in component MTBF or MTTR is worth the cost in additional development. New estimated values of μ and $P(\mu/2)$ will be entered into AMSEC (by failure mode if desired), and their impact on R/M/A and support cost (or on total cost, if the cost of mission failure is known) will be calculated. These estimates will be compared against the estimated costs of additional development.

Analysis Procedure

1. Characterize each alternative proposal as to development cost (C_D) and the expected values of μ and $P(\mu/2)$ which can be provided by C_D.
2. Discuss with cognizant engineers the development risk and quantitatively specify risk (e.g., in functional form as shown in Figure III.13).
3. Enter expected values of μ and $P(\mu/2)$, along with other input data, into AMSEC and calculate expected support cost/total cost.
4. Add expected total O/S cost and expected development cost C_D.
5. Enter current values of μ and $P(\mu/2)$ and calculate support /total cost.
6. Compare results of (4) against (5). If Step (2) is a no-risk venture (e.g., a fixed price contract with warranty covering failure to meet specs) then the minimum cost alternative is preferred.

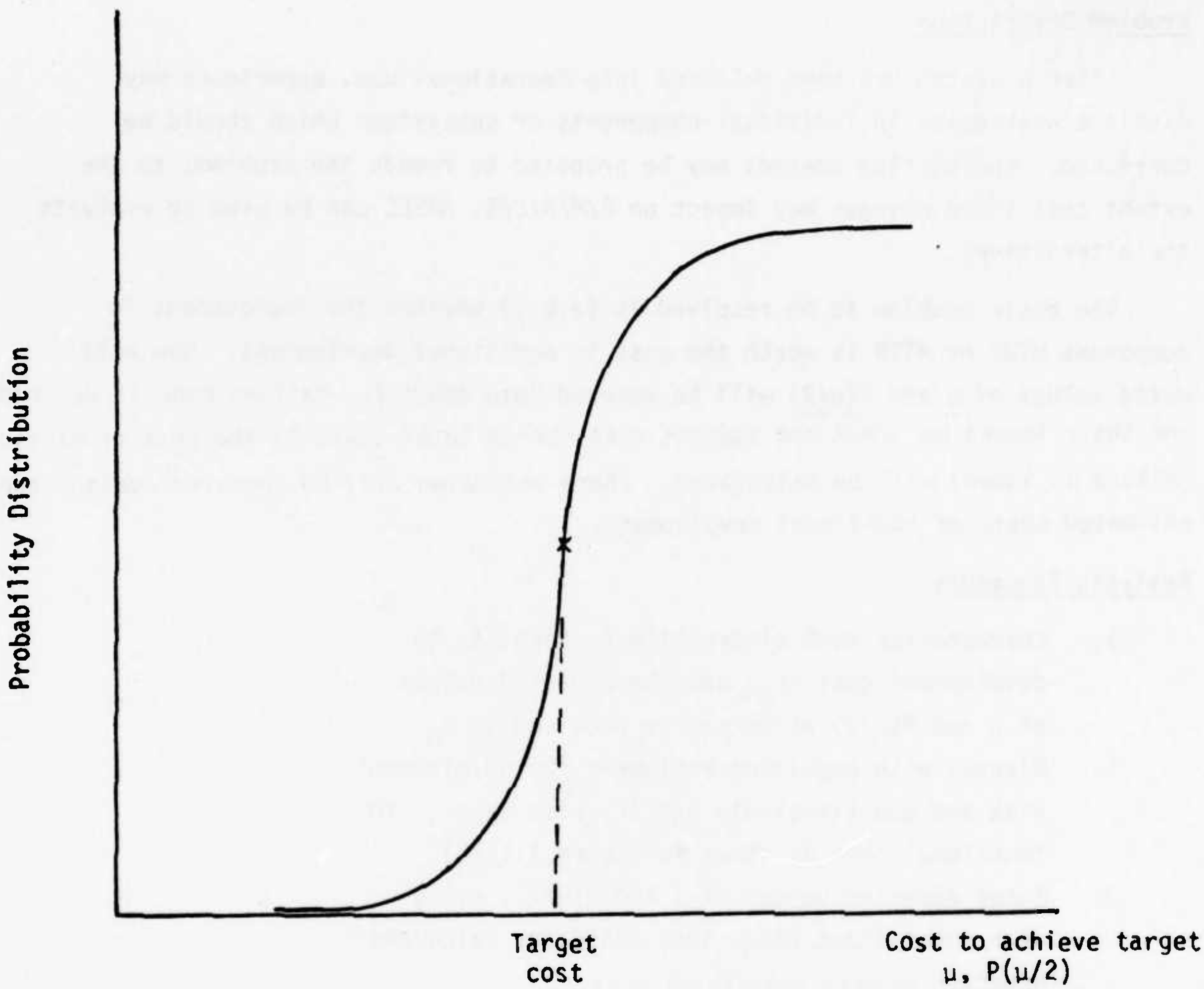

FIGURE III.13. ILLUSTRATIVE PROBABILITY DISTRIBUTION OF COST TO ACHIEVE ECP OBJECTIVES

7. Recalculate (6) using cost corresponding to 90 percentile confidence (Figure III.13). Iterate for other percentiles.
8. Estimate percent confidence at break-even point for trade-off between Step (4) and Step (5).
9. Identify decision and related risk from Step (8) for management choice.

LEVEL-OF-REPAIR-SELECTION

Problem Description

A major area for maintenance planning lies in the specification of the echelon level at which repair actions on a component will take place. For a given component, the decision may be different for different modes of failure. The RMAC related parameters which are sensitive to this decision include:

1. Cost of labor in making repair.
2. Cost of material, special tools and equipment to provide repair capability.
3. Logistic delay time in transferring between maintenance levels.
4. Delay time awaiting service, parts, etc.
5. Probability of successful repair.
6. Calendar time to carry out repair.
7. Logistic shipping and storage costs.
8. Maintenance skill level required for repair.
9. Disposition cost of material.

The calculation of these values and the mapping of the results into the AMSEC input parameters which they implicitly define, involves consideration of (a) the distances to field operations theater, (b) assignment of MOS skill levels to maintenance levels, and equipment allocation, (c) locations of shipping and supply points, etc. Once the alternative geometries and allocations are established, the corresponding AMSEC inputs can be calculated, and the cost-effectiveness of the alternative LOR distributions can be evaluated.

Analysis Procedure

1. Lay out current configuration of maintenance activities, skill levels, equipments, distances.
2. Identify repair times, MOS and equipment requirements for the i^{th} component in the j^{th} mode of failure.
3. Identify current feasible alternatives where the work W_{ij} can be done.
4. For each alternative location, calculate set of AMSEC input values for those parameters effected

by the change (e.g., repair time distribution, labor cost for repair, etc.). At the moment this mapping of LOR configuration to AMSEC input parameter value is manual. An extension to AMSEC could provide a direct translation so that the field configuration and logistic parameters could be direct inputs.

5. Calculate RMACS consequences for each alternative under investigation.
6. Select preferred (e.g., minimum cost) configuration.
7. Examine sensitivity of selection to changes in the way each facility is staffed/equipped. Determine desirable changes in existing configuration.

APPENDIX A
GLOSSARY OF TERMS

The following pages define the principle terms encountered in the analysis of system RMAC and in the use of AMSEC, as discussed in this Handbook. For convenience the Glossary is broken down by major information category.

INPUT PARAMETERS

SYSTEM CONFIGURATION

Component. . . Lowest indenture level at which maintenance/renewal actions take place.

Equipment. . . A grouping of one or more redundant components, to carry out a specific function.

Subsystem. . . A grouping of equipments.

System . . . . The entire configuration, comprising all equipments.

N. . . . . . . Number of equipments in system.

n_k . . . . . . Number of components in k^{th} equipment.

X_k . . . . . . Number of operable components required for k^{th} equipment mission readiness.

X'_k. . . . . . Number of operable components required for k^{th} equipment mission completion.

LIFE CHARACTERISTICS

For k^{th} component:

m_k . . . . . . Number of mission failure modes.

$S_{k,j}$ . . . . . Number of mission stages leading to mission failure for each of j modes. Each "stage" represents the life distribution corresponding to a different hazard or combination of hazards. $S_{k,j}=1,2$.

$S'_{k,j}$. . . . . Type of distribution for each of the $S_{k,j}$ stages. Two general distributions are provided for:

1. Two parameter Weibull, viz., $p(t) = \exp - At^B$ where any two of following need be specified A (location); B (shape); $\mu = \Gamma\ (1/B+1)\ A^{-1/B}$, (mean);

   Or $\rho(\mu/2) = \exp - \{\Gamma(1/B + 1)/2\}^B$, probability anomaly occurs after one-half mean argument.

2. Linear segment - read in point coordinates (argument, probability of survival) as many points as desired. The linear segments, by accomodating observations of anomalies can display any combination of steps that correspond to actual use conditions.

COMPONENT MAINTENANCE/SERVICE

For k^{th} component:

$1-\delta_k$ . . . . . (Constant) probability of handling/transportation (H/T) failure between missions.

$\gamma_{1k}(t)=1-\beta_k(t)$ Age distribution for initiation of preventive maintenance (PM) of non-failed component.[1/]

$\gamma_{2k}(\tau)$ . . . . Probability distribution of completion of PM in time τ.[1/]

$\alpha_k(\tau)$. . . . . Probability distribution of completion of corrective maintenance (CM) failed component in time τ.[1/]

f_{ks} . . . . . Service frequency not calling for component renewal (e.g., lubrication).

h_{k0} . . . . . Man hours per service

h_{k1} . . . . . Man hours per PM.

h_{k2} . . . . . Man hours for CM per handling/transportation failure.

$h_{k4,m}$ . . . . Man hours for CM following mission failure in the m^{th} mode.

LOGISTIC SUPPORT

h . . . . . . Number of systems to be supported.

R_c . . . . . . Rebuild cycle, the operating time or mission number after which system is to be rebuilt regardless of condition.

OPERATIONAL USE

ν . . . . . . Number of system missions.

t . . . . . . Mission time.

τ . . . . . . Time between missions.

ρ_k . . . . . . Component utilization factor for k^{th} component.

$c_{k,f}$ . . . . . Failure mode criticality factor for k^{th} component.

COST BASIS

For k^{th} component:

C_{k0} . . . . . Cost ($) per service man hour.

C_{k1} . . . . . Cost ($) per PM man hour.

C_{k2} . . . . . Cost ($) per CM man hour following handling/transportation failure.

$C_{k3,m}$ . . . . Cost ($) per man hour for CM following failure in m^{th} mode, $m = 1,2,...$

C'_{k0} . . . . . Material cost ($) per service.

C'_{k1} . . . . . Material cost ($) per PM.

C'_{k2} . . . . . Material cost ($) per CM following handling/transportation failure.

[1/] α_k, $1-\beta_k$, γ_k Distributions can be expressed by (1) two parameter Weibull or (2) linear segment, as is the case for expressing component life characteristics.

$C'_{k3,m}$ . . . . Material cost (\$) per CM following failure in m^{th} mode, $m = 1,2,\ldots$

$C_{k\bar{A}}$ . . . . . Cost unavailability.

$C_{k\bar{R}}$ . . . . . Cost unreliability.

OUTPUT PARAMETERS [2/]

RAM EVALUATION

For k^{th} component:

$\Omega_k(i)$. . . . . Probability of i^{th} mission accomplishment, i.e., probability component is ready for and survives i^{th} mission, $(i = 1,2,\ldots\nu)$

$A_k(i)$ . . . . Component availability/readiness for i^{th} mission, i.e., the probability that component is operable (ready) at start of i^{th} mission.

$R_k(i)$ . . . . Component reliability during i^{th} mission, i.e., the probability that component will survive the i^{th} mission given it is ready.

$\Omega_{\xi k}(i)$ . . . . Equipment availability/readiness, the probability that the equipment will accomplish ith mission.

$A_{\xi k}(i)$ . . . . Equipment availability/readiness, the probability that the equipment will be operable (ready) at start of i^{th} mission.

$R_{\xi k}(i)$ . . . . Equipment reliability, the probability that equipment will complete mission given it is operable at start.

$\Omega_s(i)=\prod_k \Omega_{\xi k}(i)$ System accomplishment, the probability all (or specified) equipments in system are ready and survive i^{th} mission.

$A_s(i)=\prod_k A_{\xi k}(i)$ System availability/readiness, the probability all (or specified) equipments in system will be operable at start of i^{th} mission.

$R_s(i)=\prod_k A_{\xi k}(i)$ System reliability, the probability all (or specified) equipments will complete i^{th} mission given they are ready.

Ω_{sk} . . . . . Probability that h systems operating for t time units will require renewal (sparing) s for less components of k^{th} type (i.e., protection level for k^{th} component.

EVENT STATISTICS

For k^{th} component:

$E_{k0}(\nu)$ . . . . Expected number of service actions (SA's) over ν missions.

$E_{k1}(\nu)$ . . . . Expected number of preventive maintenance actions (PM's) completed on time over ν missions.

[2/] The terms for reliability and availability assume that criteria for determining component operability have been set forth. Criteria may vary to reflect various levels of component performance/safety which are of interest. Changing performance requirements will also impact on component life characteristic parameter inputs, e.g., Weibull A and B parameters.

$E_{k2}(\nu)$ . . . . Expected number of handling/transportation (H/T) failure over ν missions.

$E_{k3}(\nu)$ . . . . Expected number of PM;s not completed on time (induced failure) over ν missions.

$E_{k4}(\nu)$ . . . . Expected number of mission failures (all modes) over ν missions.

$E_{k4,m}(\nu)$ . . . Expected number of mission failures in m^{th} mode over ν missions.

$E_{k5}(\nu)$ . . . . Expected number of CM's completed on time over ν missions.

$E_{k6}(\nu)$ . . . . Expected number of CM's not completed on time over ν missions.

$E_{k7}(\nu)$ . . . . Expected number of maintenance actions (MA's) not completed on time (NORS + NORM) over ν missions.

COST OUTPUTS

Cumulative costs over system operating time for equipment/system by:

Labor as re:

- Service actions
- Preventive maintenance actions
- Corrective maintenance actions
- Corrective maintenance actions by failure mode.

Material as re:

- Service actions
- Preventive maintenance actions
- Corrective maintenance actions
- Corrective maintenance actions by failure mode.

Unavailability

Unreliability

SPARES

$W_k(h,\nu)$ Number of spares of k^{th} equipment which will support h systems through a period of ν missions with probability Q_k.

MISCELLANEOUS TERMS

FMEA	Failure mode and effects analysis
LOR	Level of repair
TBO	Time-between-overhaul
MEA(D)	Maintenance Engineering Analysis (document)
LRU	Line replaceable unit
SRU	Ship replaceable unit
TRADOC	Training and doctrine
LSA	Logistic support analysis
PM	Project Manager (management)
pm	Preventive maintenance
cm	Corrective maintenance
RAM/LOG	Reliability, Availability, Maintainability, Logistics
ECP	Engineering Change Proposal
S	Spares
DIR	Dissassembly, Inspection, Report
MOS	Military operational speciality organization

APPENDIX B

ALGORITHM FOR OBTAINING COMPONENT RENEWAL DISTRIBUTION BY CAUSE

IMPACT OF REMOVAL CRITERIA ON EQUIPMENT SERVICE TIME

In maintaining equipment performance and safety in aircraft operation an equipment is "renewed" from time to time through removal and replacement with a new or overhauled equipment. How frequently renewal takes place depends on the various reasons that exist for removal and the distribution of flight hours necessary to satisfy such reasons.

For many aircraft components, the Army Aviation Systems Command maintains records through the RAMMIT data collection program depicting the distribution of component flight hours to removal (renewal) by cause of removal. These records are known by the acronym "MIRF" meaning Major Item Removal Frequency. The MIRF documents in summarizing item renewal frequencies distribute the number of renewals by cause into 100 flight hour time intervals since last prior renewal.

To estimate the impact which a particular cause for removal has on the operating life of an equipment, it is necessary to determine the distribution of flight hours to removal by cause conditional on the non-interruption of the distribution from other causes. Assuming causes for removal are mutually independent the probability, $R(T)$, that an item will survive T flight hours without being renewed is given by

$$R(T) = \prod_{j=1}^{k} R_j(T) \tag{1}$$

where $R_j(T)$ is the probability that the j^{th} cause for renewal will not take place in T flight hours. It is the purpose of this note to provide a method for estimating $R_j(T)$ using MIRF data.

Estimation of R_j

In developing an estimate of R_j let the following notation apply. Let

$i = 1, 2, \ldots$ connote the time interval when removal for any cause takes place

t = flight hours covered by an interval

For MIRF recording t has been set equal to 100 flight hours.

n_{ij} = number of observed renewals for j^{th} cause in i^{th} time interval

$$n_i = \sum_{j=1}^{k} n_{ij} = \text{number of observed renewals for all causes}$$

in i^{th} time interval (total number of possible causes equals k).

$$n = \sum_{i=1}^{m} n_i = \text{total number of observed renewals for all causes}$$

over all time intervals, $(n_{i>m} = 0)$.

In estimating R_j an assumption is made regarding the nature of the hazard of removal (removal rate) by cause, namely, that it remains constant for each cause within a time interval. Change in the hazard will thus be permitted between time intervals but not within time intervals. Given this situation, the probability, $R_j(it)$ equates to

$$R_j(it) = e^{-\sum_{\nu=1}^{i} \lambda_{\nu j} t} \quad \text{from which it} \tag{2}$$

follows that $$R(it) = \prod_{j=1}^{k} R_j(it) = e^{-\sum_{\nu=1}^{i} \lambda_\nu t} \tag{3}$$

where $\lambda_\nu = \sum_{j=1}^{k} \lambda_j$. Now with the assumption of constant failure rate within an interval, say the ν^{th} interval for each cause, it is well known that given a removal in the ν^{th} interval, that $\lambda_{\nu j}/\lambda_\nu$ equates to the probability that the j^{th} cause will be the cause for removal. This probability can be estimated from the statistic $n_{\nu j}/n_\nu$. From equations (2) and (3) it follows that

$$\frac{R_j(\nu t)}{R_j[(\nu-1)t]} = \left[\frac{R(\nu t)}{R[(\nu-1)t]}\right]^{\lambda_{\nu j}/\lambda_\nu} \quad \text{since} \tag{4}$$

$$\frac{R_j(\nu t)}{R_j[(\nu-1)t]} = e^{-\lambda_{\nu j} t} \quad \text{and} \quad \frac{R(\nu t)}{R[(\nu-1)t]} = e^{-\lambda_\nu t}$$

Taking the product of $R_j(\nu t)/R_j[(\nu-1)t]$ over ν

$\nu = 1$ to i yields the equation

$$R_j(it) = \prod_{\nu=1}^{i} \left[\frac{R(\nu t)}{R[(\nu-1)t]} \right]^{\lambda_{\nu j}/\lambda_\nu} \qquad (5)$$

Substituting sample estimates for $R(\nu t)$ and $\lambda_{\nu j}/\lambda_\nu$

$\nu = 1, 2, \ldots, i$ yields

$$\hat{R}_j(it) = \prod_{\nu=1}^{i} \left[\frac{1 - \frac{\sum_{x=1}^{\nu} n_x}{n}}{1 - \frac{\sum_{x=1}^{\nu-1} n_x}{n}} \right]^{\frac{n_{\nu j}}{n_\nu}} \qquad (6)$$

as an estimator of $R_j(it)$.

APPENDIX C

ANALYSIS METHODOLOGY AND PROGRAMMING OF AMSEC

The original analytic formulation and the computer programs covering the AMSEC methodology were delivered to the Army under Subcontract to Parks College of St. Louis University in TR 8-R-1.[1/] Since the initial delivery, AMSEC capabilities have been extended; this handbook addresses the development and application of the most current version.

This section focuses on the mathematical modifications which have been made in AMSEC since the referenced report. A mathematical formulation has been added to separate out different causes of system outage (e.g., unavailability due to planned maintenance) as possible generators of different man-hour involvements and cost differences reflecting different material/facility requirements. A further formulation has been added which provides for aggregation of support cost estimates by mode of component failure/removal. Appendix C-1 sets forth the mathematical basis for AMSEC, and Appendix C-2 provides computer documentation. All computer programs have been delivered to AVSCOM, the fully updated methodology has now been set up on AVSCOM's computers, and is ready to use. Appendix D provides an illustration of the use of the current version of the methodology.

[1/] COBRO TR 8-R-1, "Analysis of AH-1G Engine and Drive Train Reliability, Availability, and Support Costs," 31 January 1974, prepared under subcontract to Parks College of St. Louis University. See page C-3 for material drawn from this report for completeness of documentation.

APPENDIX C.1
MATHEMATICAL BASIS

BACKGROUND

Mathematical formulations which AMSEC uses to determine equipment RAMC were delivered to AVSCOM as part of COBRO TR 8-R-1, "Analysis of AH-1G Engine and Drive Train Reliability, Availability and Support Cost," dated 31 January 1974. Two versions of AMSEC were delivered: the steady-state and the non-steady-state with the latter version more extensive and capable of driving out values of equipment RAMC as the equipment progresses in age. For convenience and ready reference the non-steady state version, Appendix D.2 of TR 8-R-1, exclusive of the computer programming documentation is included in this appendix.

The mathematics of AMSEC considers a system made up of replaceable units each capable of failure independent of other units and each forming a "package" for which there are necessary support requirements. These units are specifically described in mathematical fashion relative to their behavior under real or postulated operational environments/assignments and support conditions. It is these replaceable units which AMSEC mathematics forms in "product" fashion to produce system RAMC outputs.

In setting forth the mathematics of AMSEC for use with the handbook certain changes have been accomplished. For the most part these changes have augmented the capability of AMSEC to reflect "real world" conditions. Other changes were undertaken to limit the required number of input variables necessary to drive AMSEC. These changes coupled to the modified computer programs permitted the development of work-oriented input/output data formats.

In modifying AMSEC for the handbook, the following input variables have been fixed: mission time, t_i, for the i^{th} mission set equal to t for all missions; τ_i, time between i^{th} and $(i+1)^{th}$ mission set equal to τ for all missions, and $\rho_K(i)$, the useage rate of the K^{th} item/equipment in i^{th} mission set equal to ρ_K for all missions.

The conditional probabilities $\beta_K(it,\tau)$ and γ_K (it,τ) respectively that an equipment which has aged (it) time units will be left to continue aging or be removed in time τ or less have been modified for expression as distributions with argument (it). At present AMSEC is programmed for expression of β and γ as

Weibull or linear segment. The probabilities $\gamma_k(it)$ and $\gamma_k(\tau)$ called γ_1 and γ_2 in the program are factors of the product $\gamma_k\,(it, \tau)$. Thus $\gamma_k(it)$ becomes the probability that renewal is initiated on a non-failed item after it has aged (it) units and $\gamma_k(\tau)$ is the probability that renewal, if initiated, will be completed before the next mission commences.

BASIC AMSEC FORMULATION

The following material presents the basic non-steady formulation of AMSEC and is drawn from Appendix D.2 of COBRO TR 8-R-1, as referenced above.

FORMULATION OF EQUIPMENT MISSION RELIABILITY AND AVAILABILITY

Definition of Terms

Let

ν = number of missions since system assembly $\nu = 1,2,\ldots$

t_i = system time to complete i^{th} mission $i = 1,2,\ldots,\nu$

$\rho_k(i)$ = usage rate of k^{th} renewable system component in i^{th} mission

τ_i = time between i^{th} and $(i+1)^{th}$ mission.

Given k^{th} component in failed condition, let

$\alpha_k(\tau_i)$ = probability maintenance following i^{th} mission will renew component in time τ_i or less

$1-\alpha_k(\tau_i)$ = probability maintenance following i^{th} mission will not renew component in time τ_i or less

Given k^{th} component in non-failed condition, let

$\beta_{kj}(\tau_i)$ = probability that maintenance following i^{th} mission will in time τ_i or less permit component which was last renewed after $(i-j)^{th}$ mission (i.e., component which has been aged, $\rho_k(i-j+1)\,t_{k-j+1} + \rho_k(i-j+2)\,t_{i-j+2} + \ldots + \rho_k(i)t_i$, since last renewed) to remain in equipment as is for subsequent operation; $j=1,2,\ldots,i$

$\gamma_{kj}(\tau_i)$ = probability that maintenance following i^{th} mission will in time τ_i or less renew component which was last renewed after $(i-j)^{th}$ mission (i.e., component which has aged $\rho_k(1-j+1)t_{i-j+1} + \rho_k(1-j+2)t_{i-j+2}+\ldots + \rho_k(i)t_i$ since last renewed)

$1-\beta_{kj}(\tau_i)-\gamma_{kj}(\tau_i)$ = probability that maintenance, following i^{th} mission will in time τ_i or less induce failure in component which was last renewed after $(i-j)^{th}$

mission and subsequently not renew component prior to start of (i+1)th mission (e.g., initiate but not complete maintenance action in time τ_i or less such that component is in non-ready condition upon mission arrival).

Further let $\delta_k(i)$ = probability that handling/transportation of component between maintenances following $(i-1)^{th}$ and i^{th} missions will not cause failure

$r_k\{\rho_k(1)T_1\}$ = probability that component that is operable at start of first mission will survive operating time $\rho_k(1)T$.

$r_k\left\{\sum_{i=\nu-j+1}^{\nu}[\rho_k(i)]t_i + [\rho_k(\nu+1)]T_{\nu+1}\right\}$ = probability that item will survive an operating time

$$\sum_{i=\nu-j+1}^{\nu}[\rho_k(i)]t_i + [\rho_k(\nu+1)]T_{\nu+1}$$

if not failed or renewed by maintenance or handling between missions

where T_1 = system time into 1st mission

$T_{\nu+1}$ = system time into $(\nu+1)^{th}$ mission.

With the above parameter definitions, it can be shown by induction that the probability that the k^{th} component will be operable at time $T_{\nu+1}$ into the $(\nu+1)^{th}$ mission is

$$\Omega_k(1) = \Omega_k\{\rho_k(1)T_1\} = \delta_k(1)\,r\{\rho_k(1)T_1\}$$

for the first mission and

$$\Omega_k(\nu+1) = \Omega_k\left\{\sum_{i=1}^{\nu}\rho_k(i)t_i + \rho_k(\nu+1)T_{\nu+1}\right\} \quad (1$$

$$= \alpha_k(\tau_\nu)\,\delta_k(\nu+1)\left[1-\sum_{j=1}^{\nu}P_{kj}(\nu)\right]r_k\{[\rho_k(\nu+1)]T_{\nu+1}\}$$

$$+\ \delta_k(\nu+1)\sum_{j=1}^{\nu}\gamma_{kj}(\tau_\nu)P_{kj}(\nu)r_k\{[\rho_k(\nu+1)]T_{\nu+1}\}$$

$$+\ \delta_k(\nu+1)\sum_{j=1}^{\nu}\beta_{kj}(\tau_\nu)\,\frac{r_k\left\{\sum_{i=\nu-j+1}^{\nu}[\rho_k(i)]t_i + [\rho_k(\nu+1)]T_{\nu+1}\right\}}{r_k\left\{\sum_{i=\nu-j+1}^{\nu}[\rho_k(i)]t_i\right\}}P_{kj}(\nu);$$

for the $(\nu+1)^{th}$ mission, $\nu=1,2,\ldots$

where necessary to the formulation are the recursion equations

$$P_{k1}(1) = \delta_k(1) r_k \{[\rho_k(1)\ t_1\}$$

$$P_{k1}(i) = \alpha_k(\tau_{i-1})\left[1 - \sum_{j=1}^{i-1} P_{kj}(i-1)\right] r_k\{[\rho_k(i)]t_i\}\,\delta_k(i)$$

$$+ \sum_{j=1}^{i-1} \gamma_{kj}(\tau_{i-1})\, P_{kj}(i-1)\, r_k\{[\rho_k(i)]t_i\}\,\delta_k(i)$$

$$P_{kj}(i) = \beta_{k,(j-1)}(\tau_{i-1}) \frac{r_k\left\{\sum_{x=i-j+1}^{i} [\rho_k(x)]t_x\right\}}{r_k\left\{\sum_{x=i-j+1}^{i-1} [\rho_k(x)]t_x\right\}} P_{k,(j-1)}(i-1)\delta_k(i)$$

$$(j = 2, 3, \ldots, i), \quad (i = 2, \ldots, \nu)$$

$P_{kj}(i)$ is the probability that the k^{th} component will be operable at end of i^{th} mission and will have been last renewed by maintenance after the $(i-j)^{th}$ mission.

Setting $T_{\nu+1} = t_{\nu+1}$ in Ω_k and dividing by $\nu+1$ gives the expected proportion (average) of $(\nu+1)$ missions accomplished by the k^{th} component, viz.,

$$\frac{\sum_{j=0}^{\nu} \Omega_k\left\{\sum_{i=1}^{j+1} \rho_k(i)t_i\right\}}{\nu+1} \text{ for } (\nu+1) \text{ missions, } \nu = 0, 1, 2 \ldots . \tag{2}$$

Average Component Mission Availability

Permitting $T_{\nu+1}$ to approach zero from the right in Ω_k and dividing by $\nu + 1$ gives the expected proportion of missions for which the k^{th} component is available, viz.,

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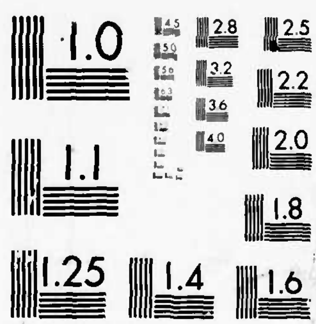

1.0
4.5
5.0
5.6
6.3
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

$$\bar{A}_k(\nu+1) = \frac{\sum_{j=0}^{\nu} \lim_{T_{j+1} \to 0^+} \Omega_k(j+1)}{\nu+1} = \frac{\sum_{j=0}^{\nu} \lim \Omega_k(j+1)}{\nu+1} \tag{3}$$

for $\nu+1$ missions, $=0, 1, 2, \ldots$.

This expresses average component mission availability over $\nu+1$ missions.

Average Component Mission Reliability

Defining mission reliability as the expected proportion of missions accomplished for which the k^{th} component is available gives

$$\bar{R}_k(\nu+1) = \frac{\sum_{j=0}^{\nu} \Omega_k(j+1)/\lim \Omega_k(j+1)}{\nu+1} \tag{4}$$

for $(\nu+1)$ missions, $\nu = 0, 1, 2, \ldots$.

System Average Mission Availability

Defining $\bar{A}_s(\nu+1)$ as average system mission availability for $(\nu+1)$ missions, it can be shown that

$$\bar{A}_s(\nu+1) = \frac{\sum_{j=0}^{\nu} \prod_{k=1}^{N} \sum_{x=x'_k}^{n_k} C_x^{n_k} \left[\lim \Omega_k(i+1)\right]^x \left[1-\lim \Omega_k(j+1)\right]^{n_k-x}}{\nu+1}$$

$\nu = 0, 1, 2, \ldots$

where N = number of mission required equipments in system containing one or more redundant items of k^{th} type

n_k = number of redundant components of k^{th} type in each required equipment

x'_k = least number of items of k^{th} type which must be operable at beginning of mission to satisfy subsystem availability requirements.

Average System Mission Reliability

Similarly for average system mission reliability for $\nu+1$ missions, say $\bar{R}_s(\nu+1)$, it can be shown that

$$\bar{R}(\nu+1) = \frac{\sum_{j=0}^{\nu} \sum_{k=1}^{N} \prod_{x=x_k}^{n_k} A_k(x,j) \sum_{y=x'_k}^{n_k} C_y^x \left(\frac{\Omega_k(j+1)}{\lim \Omega_k(j+1)}\right)^x \left(1 - \frac{\Omega_k(j+1)}{\lim \Omega_k(j+1)}\right)^{x-y}}{\nu + 1} \tag{6}$$

where $A_k(x,j) = C_x^{nk} (\lim \Omega_k(j+1)^x (1 - \lim \Omega_k(j+1))^{nk-x}$.

$x_k \geqslant x'_k$ = least number of components of k^{th} type which must be operable at conclusion of mission to satisfy subsystem reliability requirements.

NOTE: Dropping the Operator Π in Equations (5) and (6) provides the expressions for equipment average mission availability and reliability, respectively.

FORMULATION FOR DETERMINING EQUIPMENT SPARES PROVISIONING LEVELS

Under definition of parameters, as said earlier, let,

$$t_i = t,$$

$$\tau_i = \tau,$$

$$\rho_k(i) = \rho_k, \text{ and}$$

$$\alpha_k(\tau_i) = \alpha_k$$

$$\delta_k(i) = \delta_k \qquad \text{for all } i,\ i = 1, 2, \ldots, \nu$$

Further let

$$\beta_{kj}(\tau_i) = \beta_{k,u} \qquad u = (i-j) = 0, 1, \ldots, \nu;$$

$$\gamma_{kj}(\tau_i) = \gamma_{k,u} \qquad \beta_{ko} = 1;\ \gamma_{ko} = 0$$

Under these conditions, it can be verified that the distribution of missions between replacements of k^{th} item satisfies the conditions for a renewal process. This distribution is characterized by the following statement, namely the probability, say, $A_{k,n}$, that the k^{th} component will be used for exactly n missions before being replaced is

$$A_{k,n} = \delta_k^n\, r(n\,\rho_k\, t)\left[\prod_{u=0}^{n-1} \beta_{ku}\right]\gamma_{k,n} + \left[1 - r(\rho_k t)\,\delta_k\right](1-\alpha_k)^{n-1}\alpha_k \tag{7}$$

$$+ \sum_{u=1}^{n-1}\left[\delta_k^u (1-\alpha_k)^{n-u-1}\,\alpha_k \left[\prod_{i=0}^{u-1}\beta_{ki}\right]\left\{(1-\gamma_{ku})\, r(u\,\rho_k t) - \beta_{ku}\, r\left[(u+1)\,\rho_k t\right]\delta_k\right\}\right]$$

$$n \geq 2,\ \beta_{ko} = 1,\ \gamma_{ko} = 0$$

$$A_{k,1} = \delta_k \, r(\rho_k t) \, \gamma_{k1} + \left[1 - r(\rho_k t)\, \delta_k\right] \alpha_k$$

Because A_{kn} as defined forms a renewal process, the distribution of equipment spares to support a given number of missions can be determined by setting up the probability generating function

$$G_k(\nu, r, S) = \left\{ \sum_{n=1}^{\nu} A_{kn} S^n \right\}^r$$

The coefficient, say $C_k(m, r, \nu)$, $1 \le r \le m \le \nu$ of S^m in the expansion of G_k is the probability that the r^{th} replacement of the k^{th} item takes place immediately following the m^{th} mission. From this it follows that the probability say $B_k(r, \nu)$ that exactly r replacements of the k^{th} item will take place in support of ν missions of a single equipment is

$$B_k(r,\nu) = \sum_{m=r}^{\nu} C_k(m,r,\nu) \left[1 - \sum_{n=0}^{\nu-m} A_{k,n}\right]; \qquad A_{k,o} = 0. \tag{8}$$

From the definition of A_k it follows of course that the probability $B_k(0,\nu)$ that zero replacements take place in supporting ν missions is simply

$$B_k(0,\nu) = \left[1 - \sum_{n=0}^{\nu} A_{k,n}\right], \qquad A_{ko} = 0. \tag{9}$$

<u>Expected Number of Total k^{th} Item Replacements to Support ν Missions</u>

By definition, the expected number of total k^{th} component replacements, say $E_k(\nu)$, to support (ν) missions is

$$E_k(\nu) = \sum_{r=0}^{\nu} r B_k(r,\nu) \tag{10}$$

Expected Number of k^{th} Item Replacements for Carrying Out Planned or Scheduled Maintenances to Support ν Missions

Following the same method underlying the development of Equation (8), it can be shown that the distribution of the number of missions (n) between k^{th} item replacements for purposes of planned or scheduled maintenance, say $A'_{k,n}$, is

$$A'_{k,1} = \delta_k r_k(t)\gamma_1, \quad n = 1 \tag{11}$$

$$A'_{k,n} = \delta_k^n r_k(nt)\left[\prod_{u=0}^{n-1} \beta_{k\mu}\right]\gamma_{kn}$$

$$+ \sum_{u=1}^{n-1}\sum_{i=1}^{u} \delta_k^{i-1} (1-a_k)^{u-i}\left[\prod_{x=0}^{i-2} \beta_{k,x}\right]$$

$$\left[r_k\,[(i-1)t]\,(1-\gamma_{k,i-1}) - \beta_{k,i}\, r_k\,(it)\,\delta_k\right] a_k\, A'_{k,n-u}\, n - 2; \quad n \geq 2,\ \beta_{k,-1} = 1$$

Again setting up the generating function

$$G'_k(\nu, r, s) = \left\{\sum_{n=1}^{\nu} A'_{kn}\, s^n\right\}^{r'},$$

it can be shown to follow that the coefficient, say $C'_k(m, r', \nu)$, $1 \leq r' \leq m \leq \nu$, of S^m in the expansion of G'_k is the probability that the r'^{th} replacement for purposes of planned maintenance takes place following the m^{th} mission. From this it follows that the probability, say $B'_k(r', \nu)$, that exactly r' replacements for planned maintenance of the k^{th} item will be necessary to support ν missions of a single equipment is

$$B'_k(r', \nu) = \sum_{m=r'}^{\nu} C'_k(m, r', \nu)\left[1 - \sum_{n=0}^{\nu-m} A'_{k,n}\right], \quad A'_{k0} = 0. \tag{12}$$

Again by definition, the expected number of k^{th} item replacements for planned maintenance to support ν missions, say $E'_k(\nu)$, is

$$E'_k(\nu) = \sum_{r'=0}^{\nu} r' B'_k(r', \nu) \tag{13}$$

For the expected number of unplanned replacements of the k^{th} item, say $E''_k(\nu)$, it can be readily shown that

$$E''_k(\nu) = E_k(\nu) - E'_k(\nu). \tag{14}$$

In considering equipment spares provisioning requirements for h systems, again the method of generating functions can be used to yield the probability, say $D_k(w; \nu_1, \nu_2, \ldots \nu_h)$ that exactly w replacements of the k^{th} equipment will be necessary to support $(\nu_1 + \nu_2 + \ldots + \nu_h)$ total system missions where ν_i is the number of missions scheduled for the i^{th} system, $i = 1,2,\ldots,h$. This probability is computed by setting up and expanding the generating function

$$H_k(\nu_1, \nu_2, \ldots, \nu_n; S) = \prod_{i=1}^{h} \left\{ \sum_{r=0}^{\nu_i} B_k(r, \nu_i) S^r \right\}$$

and equating $D_k(w; \nu_1, \nu_2, \ldots, \nu)$ to the coefficient of S^w in the expansion. A desired protection level for the k^{th} equipment, say Q_k (i.e., desired probability of having sufficient k^{th} equipment spares on hand) can be satisfied by determining an inventory w_k such that

$$\sum_{w=0}^{w_k-1} D_k(w; \nu_1, \nu_2, \ldots \nu_h) < Q_k \le \sum_{w=0}^{w_k} D_k(w; \nu_1, \nu_2, \ldots \nu_h). \tag{15}$$

Taking the product viz.,

$$\prod_{k=1}^{h} \sum_{w=0}^{w_k} D_k(w; \nu_1, \nu_2, \ldots, \nu_h) \tag{16}$$

yields the protection level afforded h systems with equipment inventories $w_k, k = 1,2, \ldots, h$.

FORMULATION OF EQUIPMENT SUPPORT COST

For k^{th} item, let

$h_{k,1}$ = average man-hours per check-out and test per mission

$h_{k,2}$ = average man-hours per planned overhaul/renewal

$h_{k,3}$ = average man-hours per unplanned overhaul/renewal

$c_{k,1}$ = average cost per man-hour per check-out and test

$c_{k,2}$ = average cost per man-hour per planned overhaul/renewal

$c_{k,3}$ = average cost per man-hour per unplanned overhaul/renewal

$c_{k,4}$ = prorata cost for check-out and test equipment

$c_{k,5}$ = prorata cost for handling equipment and administrative man-hours for planned overhaul/renewal

$c_{k,6}$ = prorata cost for handling equipment and administrative man-hours for unplanned overhaul/renewal

$c_{k,7}$ = material (item) cost per planned overhaul/renewal

$c_{k,8}$ = material (item) cost per unplanned overhaul/renewal

$c_{k,9}$ = mission failure cost.

Making the necessary association of the above parameter definitions with the expected value terms developed for determining component outages by cause, the expected total cost $C_{k,\nu}$ to support ν missions each of duration t of a single equipment for the k^{th} component is:

$$C_{k,\nu} = \{(h_{k1} \cdot c_{k1} + c_{k4})\,\nu + (h_{k2} \cdot c_{k2} + c_{k5} + c_{k7})\, E'_k(\nu)$$

$$+ (h_{k3} \cdot c_{k3} + c_{k6} + c_{k8} + c_{k9})\, E''_k(\nu)\} .$$

The total expected cost C_ν to support a single system for ν missions each of duration t thus is given by

$$C_\nu = \sum_{k=1}^{N} C_{k,\nu}$$

where N = number of equipment/component requiring direct maintenance support.

EXTENDED AMSEC FORMULATIONS FOR MISSION A/R EVALUATION

As may be seen from review of basic AMSEC formulations, no demand is made by the mathematics on the parametric form of life characteristics. In programming, however, life characteristics have been constrained to accepting linear segment curves or combination of Weibull curves, each curve representing a particular mode of failure, viz.,

$$r\ (i\rho t) \ = \ \exp\ (-\sum_j A_j\ (i\rho t)^{B_j}$$

Modified formulations for this extension have been developed which now permit greater flexibility in the expression of equipment failure characteristics with respect to each mode. Expressing survival probability for the j^{th} mode, AMSEC now has the expression with argument y for distance, time, etc.

$$r_j\ (y) \ = \ r_{1j}\ (y) + \int_0^y f_{1j}(x)\ r_{2j}\ (y-x)\ dx$$

This expression permits recognition of the fact that onset of a failure mode condition may have one distribution and that the time following onset to actual failure may have another. For programming, AMSEC now accepts Weibull or linear segment form for expressing both failure onset and residual time to failure for each mode. As before, the program equates overall probability of item survival (all modes) to the product of $r_j(y)$ over j, viz.,

$$r(y) \ = \ \prod_j r_j(y)$$

Furthering AMSEC's utility, it was decided to add formulations to AMSEC permitting tabulation, by mission, of reliability and availability of an equipment consisting of two or more redundant components. Defining $n_k \geqq 1$ as the number of items in an equipment, $x_k \geqq 0$ the number required for equipment readiness (availability) and $x'_k \leqq x_k$ the number required for mission accomplishment, it follows that the k^{th} equipment availability and probability of accomplishment for the ν^{th} mission, say $A_{\xi k}(\nu)$ and $\Omega_{\xi k}(\nu)$ respectively are given by the expressions:

$$A_{\xi k}(\nu) = \sum_{x=x_k}^{n_k} C_x^{n_k} \left[\lim \Omega_k(\nu)\right]^x \left[1-\lim \Omega_k(\nu)\right]^{n_k-x} \quad * \quad \text{and}$$

$$\Omega_{\xi k}(\nu) = \sum_{x=x_k}^{n_k} C_x^{n_k} \left[\lim \Omega_k(\nu)\right]^x \left[1-\lim \Omega_k(\nu)\right]^{n_k-x} \sum_{y=x'_k}^{x} C_y^x \left[\Omega'_k(\nu)\right]^y \left[1-\Omega'_k(\nu)\right]^{x-y}$$

where $\lim \Omega(\nu) = \lim_{t\to 0^+} \Omega(\nu)$ connotes component readiness with mission time approaching zero from the right and

$$\Omega'_k(\nu) = \Omega_k(\nu)/\lim \Omega_k(\nu)$$

For equipment mission reliability, say $R_{\xi k}(\nu)$, it follows by definition that

$$R_{\xi k}(\nu) = \Omega_\xi(\nu)/A_\xi(\nu) \quad *$$

EXTENDED AMSEC FORMULATIONS FOR SYSTEM SUPPORT EVALUATION

In its earlier development, AMSEC formulations permitted calculations of the probability of r item removal/replacements for failure and r' item removal/replacements for other than failure, e.g., prevention, in ν missions. Expected number of removal/replacements prior to failure and because of failure were formulated and programmed. This permitted support cost projections to encompass differential cost estimates for men and material associated with item failures and non-failures.

Since differential costs may be associated with component removal/replacement for failure prevention, for failure due to transportation or handling, for failure due to deficiency in maintenance personnel or gear, and for failure due to mission stress, AMSEC was modified to permit calculation of costs as they may distribute by component over the above causes for comoonent removal/replacements.

The earlier version of AMSEC formulated A_{kn}, the probability that the k^{th} component would be used for exactly n missions before being replaced/renewed for whatever cause. It also formulated the probability A'_{kn} that the k^{th} component would be renewed replaced for cause other than failure (e.g., scheduled renewal) after completing exactly n missions.

By partitioning the expression $A_{k,n}$, say, $A_{k,n} = \sum_{j=1}^{4} a_{knj}$

it can be shown (dropping for convenience the subscript k to denote component) that

* The equations for availability, $A_{\xi k}$ and mission reliability, $R_{\xi k}(\nu)$ are identical in substance to the expressions under the operators $\Sigma\ \Pi$ of equations (5) and (6), p. C-6 and C-7. In TR 8-R-1, the term $A_k(x,j)$ in equation (6), p. C-7 was omitted in error.

$$a_{n,1} = \delta^n \, r(nt) \left[\prod_{x=0}^{n-1} \beta\,(xt) \right] \gamma(nt,\tau)$$

is the probability that first renewal/replacement of component since last renewal encompasses exactly n missions and is caused by a non-failed condition;

$$a_{n,2} = \sum_{i=1}^{n} \delta^{i-1} \, (1-\delta) \; r\,[(i-1)t] \left[\prod_{x=0}^{i-1} \beta\,(xt) \right] [\,1-\alpha\,(\tau)]^{n-i} \; \alpha(\tau)$$

is the probability first renewal/replacement since last renewal comes after exactly n missions because of a transportation or handling failure;

$$a_{n,3} = \sum_{i=2}^{n} \delta^{i-1} \; r\,[\,(i-1)\;t] \left[\prod_{x=0}^{i-2} \beta\,(xt) \right] \left[1-\beta\,(n-1)t - \gamma[(n-1)t,\,\tau] \right] [1-\alpha\,(\tau)]^{n-1} \;\; \alpha(\tau)$$

is the probability of a maintenance induced failure (e.g., failure to complete preventive maintenance action (PM) before next mission), causing first renewal/replacement after exactly n missions; and lastly,

$$a_{n,4} = \sum_{i=1}^{n} \delta^{i} \left[r\,[\,(i-1)t\,] - r(it) \right] \left[\prod_{x=0}^{i-1} \beta(xt) \right] \cdot [1-\alpha(\tau)]^{n-i} \; \alpha(\tau)$$

is the probability that first renewal/replacement since last renewal encompasses exactly n missions and is caused by mission failure.

Using the above expressions, the probability A_{nj} that renewal/replacement for j^{th} cause will occur after exactly n missions, can be shown to be:

$$A_{n,j} = \sum_{i=1}^{n-1} (A_i - a_{i,j})\, A_{n-i,j} + a_{n,j}$$

$$j = 1,\,2,\,3,\text{ and }4$$

$A_{n,j}$ permits interlacing of reasons for renewal/replacement. It considers only that there will be n missions of the system between replacements of an item for the j^{th} cause only. As an excercise it is relatively straightforward to show

that A_{n1} in the "new" expression equates of A'_n the probability of n missions between item renewal/replacement for cause other than failure in the "old" expression as set forth on page C-10.

Paralleling the earlier developments of the probability $\beta(r,\nu)$ of exactly r replacements (spares) taking place in ν missions for all causes, the probability $\beta(r_j,\nu)$ of exactly r_j replacements in ν missions for the j^{th} cause j = 1,2,3,4 can be computed. This simply requires substitution of the A_{nj}'s for A_n in the expression for G, the generating function, and B as expressed in the earlier version as presented on C-9. Once the $B(r_j,\nu)$'s are computed it follows by definition that the expected number of replacements for j^{th} cause is given by:

$$E(r_j, \nu) = \sum_{r_j=0}^{\nu} r_j B(r_j,\nu)$$

and that under the "old" version $E(\nu)$, the expected number of replacements in ν missions for all causes, becomes:

$$E(\nu) = \sum_{j=1}^{4} E(r_j, \nu)$$

As regards item sparing requirements for h systems and ν missions the probability $\beta(r,\nu)$ of r total replacements for all causes is included in the generating function for determining the probability that W spares will be sufficient for mission support purposes. Again if distribution of spares requirements by cause is of interest $\beta(r_j\nu)$ can be substituted for $\beta(r,\nu)$ in the generating function H of the "old" AMSEC formulation.

With respect to support cost projections, the cost notation was modified to consider, in addition to man-hour and material costs associated with expected number of equipment renewal/replacements for failure and non-failure in ν missions, the costs associated with routine service requirements (e.g., item lubrication), item non-availability and non-reliability. The "new" cost definition can be found on p. A.3 of the Glossary, Appendix A.

FURTHER EXTENSION OF AMSEC FOR SYSTEM SUPPORT COST EVALUATION

In partitioning support costs and system unreliability among different kinds of component/subsystem failure mechanisms, it is first necessary to determine the distribution of mission failures by mode where two or more modes of component failure exist. The basic AMSEC formulation permits the insertion of inputs relevant to mode failure distributions and the total impact of the distributions in combination with specified plan(s) for system use and maintenance support are developed in terms of component/subsystem/system mission unreliability. Assuming that different manifestations of component failure may have different cost and aircraft safety implications, the present formulations do not permit statistical estimation of such costs and/or the degree of prevalence of aircraft safety hazard.

The purpose of this extension is to permit a more extensive analysis of the cost and safety implications of different modes of component mission failure and their aggregate impact on total system support costs and overall safety.

On Page C-16 the expression is given for a_{n4}, for the probability that a first renewal of a component since its last renewal will be caused by mission failure and cover exactly n missions. This expression is stated in mathematical terms, viz.,

$$a_{n,4} = \sum_{i=1}^{n} \delta^{i} \Big[r[(i-1)\,\rho t] - r(i\rho t)\Big]\Big[\prod_{x=0}^{i-1} \beta(x\rho t)\Big]\,[1-\alpha(\tau)]^{n-i}\,\alpha(\tau)$$

in all equations that follow where the parameters δ, β, α, ρ, and t are defined in Appendix A, pages A-2 and A-3 and $r = \Pi r_j$ component survival probability over all modes, as shown on page C-14.

Expressing a_{n4} in terms of the failure density function for mission failure, we have

$$a_{n,4} = \sum_{i=1}^{n} \delta^{i} \int_{(i-1)t}^{it} f(y)\,dy \Big[\prod_{x=0}^{i-1} \beta\,(x\rho t)\Big]\,[1-\alpha(\tau)]^{n-i}\,\alpha(\tau)$$

where $$f(y) = \frac{d}{dy}\,[1-r(y)]\ ; \quad \int_{(i-1)\rho t}^{i\rho t} f(y)\,dy = \Big[r(i-1)\rho t - r(i\rho t)\Big]$$

From this expression, we proceed to formulate the probability, say, a_{n4m}, that exactly n missions take place between component renewal/replacement and that the reason for renewal is component mission failure (designated by the index "4") in the m^{th} mode.

Assuming distributions associated with the different component failure modes are independent one of the other the probability say $P_m(t)$ that failure in the m^{th} mode will take place (i.e., preempt other failure modes or component survival) in the interval 0,t can be shown to equate to:

$$P_m(t) = \int_0^t h_m(y)\, r(y)\, dy$$

where $r(y) = \prod_{m=1} r_m(y)$

and $h_m(y) = f_m(y)/r_m(y) = \dfrac{\frac{d}{dy}\,[1-r_m(y)]}{r_m(y)}$

is the hazard of component failure in the m^{th} mode.

To develop this relation, consider an equipment that can fail in any one of M independent ways; each way has a distribution function $F_i(t)$ and continuous density function $f_i(t)$. Now let $1-F_{\bar{m}}(t) = \prod_{i\neq m} \{1-F_i(t)\}$ represent the probability of not failing in a mode other than the m^{th} mode in the interval (0,t) and $f_{\bar{m}}(t)$ represent the density function of the distribution $F_{\bar{m}}(t)$. With these definitions, it then follows that $P_m(t)$ equates to:

$$P_m(t) = \int_0^t \int_y^\infty f_m(y)\, f_{\bar{m}}(x)\, dx\, dy$$

where x is the time (point) of component failure in any mode other than m and y is time (point) of failure in mode m. Performing the above integration, we have:

$$P_m(t) = \int_0^t f_m(y) \prod_{i\neq m} [1-F_i(y)]\; dy$$

$$= \int_0^t f_m(y)\; [1-F_{\bar{m}}(y)]\; dy$$

Defining $h_m(t)$ to be the hazard of failure with respect to the m^{th} mode, viz.,

$$h_m(t) = f_m(t) \big/ \left[1-F_m(t)\right]$$

$P_m(t)$ assumes the form

$$P_m(t) = \int_0^t h_m(y) \prod_{i=1} \left[1-F_i(y)\right] dy$$

$$= \int_0^t h_m(y)\, r(y)\, dy$$

where $r(y) = \prod_{i=1} \left[1-F_i(y)\right]$ is the probability that the equipment will not fail (in any mode) in the interval (0,y).

Substituting $h_m(y)\, r(y)$ for $f(y)$ in a_{n4} above gives the expression for a_{n4m}, viz.,

$$a_{n,4,m} = \sum_{i=1}^{n} \delta^i \int_{(i-1)\rho t}^{it} h_m(y)\, r(y)\, dy \left[\prod_{x=0}^{i-1} \beta(x\rho t)\right] \cdot \left[1-\alpha(\tau)\right]^{n-i} \alpha(\tau)$$

Expressing $r_m(y)$ in the mathematical form as shown on page C-14, viz.,

$$r_m(y) = r_{1m}(y) + \int_0^y f_{1m}(x)\, r_{2m}(y-x)\, dx$$

It follows that $h_m(y)$ takes the explicit form

$$h_m(y) = \frac{\int_0^y f_{1m}(x)\, f_{2m}(t-x)\, dx}{r_{1m}(y) + \int_0^y f_{1m}(x)\, r_{2m}(y-x)\, dx}$$

where onset of failure conditions is represented by density function f_{1m} and from onset to actual failure is represented by a second density f_{2m}.

Referring to page C-16, we note that:

$$A_{n,j} = \sum_{i=1}^{n-1} (A_i - a_{i,j})\, A_{n-i,j} + a_{nj}$$

is the probability that there will be exactly n missions between renewals for j^{th} cause. Substituting 4,m for j we have the probability that there will be exactly n missions between renewal for mission failure in the m^{th} mode, viz.,

$$A_{n,4,m} = \sum_{i=1}^{n-1} (A_i - a_{i4,m})\, A_{n-i,4,m} + a_{n,4,m}$$

Now by substitution of $A_{n,4,m}$ for $A_{n,4}$ in the generating function G (see page C-9) we can compute $B(r,4,\nu)$, the probability of exactly $r_{4,m}$ renewals in ν missions for m^{th} mode mission failures.

Cost Equations

The basic AMSEC formulation partitions component labor and material costs into three parts:

1. Those associated with service of a routine or periodic nature, e.g., lubrication
2. Those associated with component renewal as a failure prevention measure or for some other non-failed condition, and lastly
3. Those associated with component renewal because of a failed condition.

With the formulation for the distribution of component renewals by mode of failure, we proceed to delineate direct support costs by labor and material among all the causes for component renewal.

For support of k^{th} component, let

C_{k0} = Cost ($) per service man hour

C_{k1} = Cost ($) per man hour for preventive maintenance

C_{k2} = Cost ($) per man hour for corrective maintenance because of a transportation/handling failure

C_{k3} = Cost ($) per man hour for component renewal following maintenance induced failure

C_{k4m} = Cost ($) per man hour for component renewal following mission failure in the m^{th} mode.

Likewise let C'_{k0}, C'_{k1}, C'_{k2}, C'_{k3} and C'_{k4m} represent respectively cost ($) for material associated with component service, renewal prior to failure, renewal because of a transportation or handling error, renewal because of a maintenance induced failure, and renewal because of mission failure in the m^{th} mode.

Completing the necessary notation for purposes of system support costing let h_{k0}, h_{k1}, h_{k2}, h_{k3}, and $h_{k,4,m}$ represent, respectively, the man hours associated with component service, renewal prior to failure, renewal for transportation or handling error, maintenance induced failure, and lastly, renewal due to mission failure in the m^{th} mode. As in the basic AMSEC $C_{\bar{A}}$ and $C_{\bar{R}}$ refer to costs of component/system unavailability and unreliability (e.g., cost of mission abort) over and above man hour and material costs.

Now with computation of the $B(r_j,\nu)$'s, j=1,2,3, and 4m; m = 1,2,.., we can determine the expected number of component renewals over ν missions for:

a. Maintenance actions prior to failure (e.g., failure prevention), $E_k(r_1,\nu)$
b. Transportation or handling accidents, $E_k(r_2,\nu)$
c. Maintenance induced failures or incompleted PM actions, $E_k(r_3,\nu)$ and
d. Renewals because of m^{th} mode mission failures, $E_k(r_{4m}, \nu)$, m=1,2,...

For purposes of distributing mission failures by some assigned criticality factor (e.g., chargeable or non-chargeable for test assessment purposes) an additional index, say $\ell = 1,2,\ldots.$ can be placed with the above designator for expected mission failures by mode, i.e.,

$$E_k\ (r_{4m},\nu) \rightarrow E_k\ (r_{4m\ell},\ \nu)$$

The criticality factor ℓ, applying to several modes, permits aggregation and distribution of failure by criticality upon summation of the E_k's over a common ℓ index.

Appendix C.2

Part 1

PROGRAM EQUIPMENT-MISSION RELIABILITY AND AVAILABILITY MODEL

Version 3

Fred S. Zusman

June 8, 1976

INTRODUCTION

This Fortran computer program is an implementation of the third version of a model developed by W. Cook of COBRO to compute equipment-mission reliability and availability. A mathematical description of the model is provided in Appendix C.1. This version allows for two step failures.

SUMMARY

This program reads data describing the failure rates, repair parameters and usage characteristics of the equipments in a complete system. The output of the program is a summary for each component, each equipment and the total system of the fractions of the missions it accomplished, the fractions of missions it was available, and its mission reliability for each of specified numbers of missions. The details of the computation are given in the above mentioned paper. The program and its usage are described herein.

INPUT

After reading a set of curve inputs, the program reads sets of the input cards described in detail below and computes the values of the output parameters. After printing the results another set of input cards is read. The program stops if no more sets of data are to be read or if there are any data errors. Each set consists of control inputs and equipment inputs.

APPENDIX C.2

DOCUMENTATION OF COMPUTER PROGRAMS FOR APPLICATION OF ANALYTIC METHOD FOR SYSTEM EVALUATION AND CONTROL

Version 3

CURVE INPUT DATA BASE (CARDS OR DISK) (Unit 9) (CURVIN)

Card	Columns	Description*
1	1-10	NCURVE, number of curves to be read from the curve data base (1-100)
		For each curve, the following cards (2-3) are needed:
2	1-10	NSIZE, number of points in this linear curve or number of phases in this Weibull curve (usually 1)
	11-20	NCOPT, this curve option code:
		0 linear segment curve for which (X,Y) segment end points follow
		1 Weibull curve for which μ's and $P(\mu/2)$'s follow for each failure phase
		2 Weibull curve for which A's and B's follow for each failure stage
	21-30	NACC, figures of accuracy for Weibull computation of A and B in Weibull (usually 4) if the μ's and $P(\mu/2)$'s are given
	41-80	CURNAM, 40 character curve name for descriptive purposes
3.0		For each end point of a linear segment curve, the following card is needed (NCOPT = 0)
	1-10	Identification (NOT USED) (for sequencing deck-safety feature)
	11-20	CURVEX, independent variable of first point
	21-30	CURVEY, dependent variable of first point
	41-80	POINAM, 40 character point I.D.--Printed on output Card 3.0 is repeated for each point with the points in order by increasing CURVEX.
OR 3.1		Weibull parameter card for first failure phase (NCOPT = 1 or 2)
	1-10	Identification (NOT USED)
	11-20	μ or A of Weibull distribution for first failure phase
	21-30	$P(\mu/2)$ or B of Weibull distribution for first failure phase ($\geq .15$)
	41-80	POINAM, 40 character distribution I.D. if desired. Card 3.1 is repeated for each phase.

*Integer fields are right justified.

Cards 2 and 3 are repeated for each linear segment of Weibull curve. The linear curves are currently looked up as a linear interpolation for data within the set of points and a linear extrapolation for data outside the point set. One-point curves are considered to be constants.

CONTROL INPUT CARDS (Unit 5) (INPUT1)

Card	Column	Description
1	1-76	ITLE, any 76 character title for run
	77-80	IPR, debug print option code
		0 ⇒ no debug print
		1 ⇒ give debug print
2	1-5	NMISS, number of missions to be run through (1-100)
	6-10	T, length of all missions (in hrs)
	11-15	Tau, interval between missions (in hrs)
	16-25	EPS, accuracy for GAUSSIAN QUADRATURE routine (usually .00001)
	41-80	MISNAM, 40 character mission name
3-7	1-80	MISDES, 5 card mission description; 5 cards required, may be blank
8	1-5	JDEL1, step for mission printout up until mission JMAX1
	6-10	JMAX1, limit for use of JDEL1
	11-15	JDEL2, step for mission printout after JMAX1

COMPONENT INPUT CARDS (Unit 5) (COMP, RDCOMP)

Card	Column	Description
1	1-10	NTYPES, number of components/equipments
		For each component/equipment, the following cards (2-4) are needed.
2	1-16	IENAME, 16 character equipment name
	21-30	XNK, number of components in this equipment
	31-40	XXK, number of components required for readiness of equipment
	41-50	XXKP, number of components required for reliability of equipment (mission success)
	68-80	IFUNAM, functional group and position of the component
3	1-16	ICNAME, 16 character name of component
	21-25	NFAILS, number of mission failure modes (1-10)
	26-30	RHO, usage rate of component
	31-35	IALPHA, curve number for computation of α as function of interval
	36-40	IBETAC, curve number for computation of β (non renewing probability) as function of time used
	41-45	IGAMM1, curve number for computation of γ_1, probability of initiating renewal) as function of time used
	46-50	IGAMM2, curve number for computation of γ_2, (renewal probability) as function of interval
	51-55	DELTA, δ (probability that handling between missions will not cause a failure)
	56-60	IRFRB, rebuild cycle (missions)
	61-80	UNIT, 20 character description of usage variable (e.g., hours)
4	1	MODTYP(1), mode type for first failure mode ($1 \Rightarrow$ use curve defined by IEVNO1, $2 \Rightarrow$ use two step failure defined by curves IEVNO1 and IEVNO2).
	2-3	IEVNO1(1), curve number to use to compute R_1 as function of time used
	4-5	IEVNO2(1), curve number to use to compute R_2 as function of time used
		If R_1, is a linear curve and MODTYP=2, then the next curve list must be f_1.
	7-12	Same data for failure mode 2.
	14-19	Etc. for up to 10 failure modes.

PROGRAM AND SUBPROGRAM DESCRIPTIONS

MAIN--Main Program

This main program calls subroutines to (1) read curve inputs, (2) read control inputs, (3) initialize totals, (4) compute the detail results and (5) print the system results. It processes all the sets of inputs on Unit 5 and then stops.

Subroutines called: CURVIN, INPUT2, INIT, COMP, PRTOT

INPUT1--Read Control Inputs

This subprogram reads and checks the control data deck. MLIST is adjusted if necessary. XNTM1 is computed (NT-1).

CURVIN--Read Curve Inputs

This subprogram reads and checks the curve data deck. The Weibull A's and B's or μ's and $P(\mu/2)$'s are computed and printed.

Subroutines called: COMPAB

INIT--Initialize System Results

This subprogram clears the mission products (PROD) and set up units 21 and 22 for the computation of PROG.

COMP--Control for Equipment Computations

This subprogram controls the computation for each equipment type. It reads the equipment data and after initializing totals computes P and Ω and the summary statistics.

Subroutine called: RDCOMP, INIT1, COMP2, COMP3, COMP4

RDCOMP--Initializes Mission Data

This subprogram reads and checks the usage and repair data for the current equipment--mission combination and computes and prints information about the equipment.

Subroutine called: COMPRK

INIT1--Initialize Equipment Totals

This subprogram clears the mission totals for the current equipment (TOT) and computes basic data for the equipment for all missions.

COMP2--Compute P

This program computes P (end-operable probability) recursively for each mission.

Subroutine called: None

COMP3--Compute OMEGA

This subprogram computes the Ω's (operable probability) for the beginning and end of each mission.

Subroutine called: None

COMP4--Compute Equipment Statistics

This subprogram computes the missions accomplished, reliability and availability for the current mission. It also steps on disk the products to compute the system totals. The results for specified missions are printed.

Subroutine called: SUMBIN

PRTOT--Print System Totals

This subprogram reads from disk and prints the summary statistics for the entire system.

COMPRK (TE1, IBFAIL, IEFAIL)

This function type subprogram computes the probability of survival (R_k) for one or more failure modes.

Subroutine called: CURVE, AUGAUS

AUGAUS (A, B, R, S, J, F, RP)

This is a standard Gaussian Quadrature routine used in this program to compute the two stage integral possibly required for the computation of R_k.

Subroutine called: None

CURVE (IX, X, IWEIBO)--Curve Look-up

This function type subprogram computes the value of the IX^{th} curve using X as the argument. Only answers between 0 and 1 are allowed and the answer may be complemented depending on IWEIBO.

Subroutine called: YLIN36

COMPAB (XMU, P,A,B, NACC)--Weibull Parameter Computation

This subprogram computes the A and B of the Weibull distribution using XMU and P with accuracy NACC (figure).

Subroutine called: WEG, GAMMA

WEG (I, XNP1, J, N)--Solve X = f(X)

This subprogram permits the iterative solution of an equation of form X = f(X).

Usage:

1st Call:	I = 1
	XNP1 = initial value on input/new value on output
	J = accuracy desired (figures)
	N = not used.
Successive Calls:	I = 2
	XNP1 = f (XNP1) from last call on input/new XNP1 on output
	J = not used
	N = 0 solution not found so recompute f (XNP1)
	N = 1 solution is XNP1.

YLIN36 (N, XL, YL, X)--Linear Curve Look-up

This function type subprogram generates the value, using X as the argument, of the function YL = f(XL) where f (XL) is a linear segment curve specified by the N points (XL, YL).

SUMB1--Compute Equipment Statistics

This subprogram computes the equipment statistics using the sum of binomial terms.

SUMBIN (XM, XL, P SUM)--Compute Binominal Sums

This subprogram generates the following sum

$$SUM = \sum_{x=x_k}^{xm} \binom{xm}{xk} P^x (1-P)^{xm-x}$$

Subroutines called: XNORM (if needed).

PRINT OUTPUT

The program generates printed outputs of the inputs as read, as well as optional de-bug information and summary results. The following discussion is broken down by output unit. A Job Deck Listing with test data can be found at the end of this section along with an example of the program output.

UNIT 6--Input and Error Message Print

CURVIN--The curve inputs are printed as read except that for the Weibull distributions.

The A's, B's, μ's and $P(\mu/2)$'s are all printed.

INPUT1--The title and mission data inputs are printed as read.

COMP-- The title is printed as well as the NTYPES input card

RDCOMP--The equipment inputs are printed as read

All error messages are printed as follows and the program usually stops.

CURVIN--NCURVE TOO BIG (NCURVE, LIMIT)
NCOPT OUT OF RANGE
NO ROOM FOR CURVES (LIMIT)
NO CURVE DATA
P TOO SMALL (P, LIMIT)

INPUT1--NMISS TOO BIG (NMISS, LIMIT)
NLIST TOO BIG (NLIST, LIMIT)

RDCOMP--IBETAC OR IGAMM1 OR IGAMM2 OR IALPHA TOO BIG
(IBETAC, IGAMM1, IGAMM2, IALPHA, LIMIT)
NFAILS TOO BIG OR SMALL (NFAILS)
BAD DATA FOR FAILS (IFAILS)
XNK, XXK, XXKP INCONSISTENT
DELTA BAD

INIT1-- GAMMA1 + BETA GREATER THAN ONE (I, GAMMA, BETA)

COMPRK--COMPRK CANNOT EVALUATE RK (ARGUMENT)

CURVE-- NCOPT NOT 0 OR 1 IN RK COMP (IX, X, IXC2, NCOPT), curve out of Range (IX, X, CURVE, L, I)

COMPAB--CANNOT SOLVE FOR A, B (XMU, P, NACC, NTIMES)

UNIT 16--Debug Print (IPR ≠ 0)

COMP2--I, J, TE3-TE5, P

COMP3--IM1, I, IT, J, SUM1-SUM3, TE1-TE9, OMEG, DELTA

COMP4--I, AC, AV, RE, XNK, TOT, SUMBAC, SUMBAV, SUMBRE, PROD

UNIT 18--Component Data and Results Print

INPUT1--The mission data are printed

RDCOMP--The equipment and component data are printed broken down by life characteristics and maintenance, frequency characteristics

INIT1 --The component life and support distribution are printed

COMP4 --The component results are printed

UNIT 19--Equipment and System Data and Results Print

INIT1 --Titling information is printed

COMP4 --The equipment results are printed

PRTDT --System results are printed

SCRATCH INPUT/OUTPUT--System Results

Units 21 and 22 are used alternately to read and update the system results as each equipment is processed. The files are binary and each logical record contains mission number and three system products (PROD). The files are explicitly referenced as follows:

INIT1 --Writes a record for each mission or unit 21 with the products set to 1. Sets the read to be from 21 and the write on 22.

COMP --Switches the read and write units after all missions are processed.

INIT1 --Both files are rewound

COMP4 --The record for the current mission is read, updated and written out again.

PRTOT --The final records are read and the system results are printed.

COMMON REAL VARIABLES

Currently the Common Real Variables are defined as REAL*4.

T	t, the length in hours of the missions
TAU	The time between missions
XMAR	Mission arrival rate
CURVEX (400)	CURVEX contains the abscissas of the linear curves and the A's or μ's for the Weibull distributions
CURVEY (400)	CURVEY contains the ordinates of the linear curves and the B's or P's for the Weibull distributions
POINAM(10,400)	The 40 character names for the 400 points
CURNAM(10,000)	The 40 character names for the 100 curves
WEIBA (400)	The A's for the Weibull distributions
WEIBB (400)	The B'es for the Weibull distributions
PROD (3)	PROD is the I^{th} product over all components for the current mission where I = 1, Accomplished I = 2, Availability I = 3, Reliability
TOT (6)	TOT (I) is the sum of the following statistics: I = 1 Equipment accomplished 2 Equipment availability 3 Equipment reliability 4 Component accomplished 5 Component availability 6 Component reliability
XNK	N_k for the current equipment (total components in the equipment)
XXK	X_k for the current equipment (total components needed for availability)
XXKP	X_k for the current equipment (total components needed for success)
ALPHA	The α for this equipment
RHO	Equipment usage rate (ρ)
DELTA	δ for this mission
UNIT (5)	20 character description of units for mission length
SUMT	SUMT is the sum of the usage at the end of the I^{th} mission going back J missions (counting the I^{th})

CAPT	Not used
DELTT	Not used
XIT	Not used
SUMBAC	Equipment fraction of missions accomplished
SUMBAV	Equipment availability
SUMBRE	Equipment reliability
OMEGA(2)	Ω at the beginning and end of the mission
AC	Component accomplished
AV	Component availability
RE	Component reliability
RHOT	Operating time (RHO*T)
RKL (100)	R_k's for the missions
BETA (100)	β's for the missions
GAMMA (100)	γ's for the missions
P (100, 2)	P (J,I) is the probability of operable at the end of the I^{th} mission if not renewed for J missions (I = 1, current, I = 2 previous mission)
RKLO	R_k at start 1st mission
SSLIFE	System service life
EPS	Definition of zero for quadrature routine
GAMMA2	γ_2

COMMON INTEGER VARIABLES

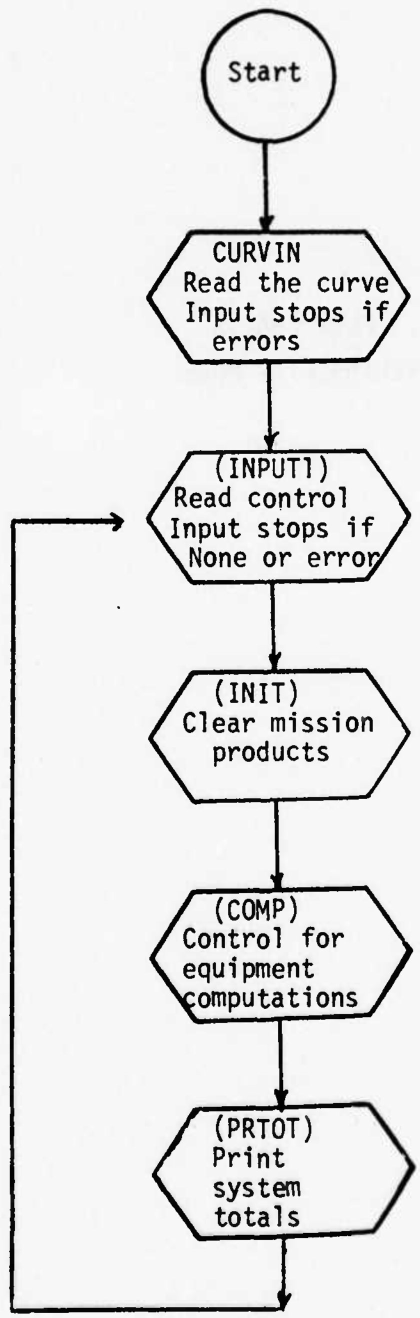
ITLE (20)	20 word (80 character) run title
NMISS	Total number of missions (1-100)
IOPT1	Not used
NTYPES	Number of equipments/components
IPR	Debug print option code 0 ⇒ no 1 ⇒ yes
NLIST	Number of missions to print (1-100)
MLIST (100)	Number of the missions to print
MSTART	Index for search of MLIST
MISNAM (10)	40 character mission name
MISDES (20,5)	5 card mission description
I	Mission number
IM1	I-1
ITYPES	Equipment number
NCURVE	Number of curves (1-100)
NSIZE (100)	Size of each curve (1-10)
NCOPT (100)	Options for each curve 0 ⇒ segment 1 ⇒ Weibull with A's and B's 2 ⇒ Weibull with μ's and P's
NACC (100)	Accuracy for Weibull computation for each curve
IBEG (100)	Starting place in the CURVEX, CURVEY lists for each curve
IENAME (4)	Equipment name
ICNAME (4)	Component name
NFAILS	Number of failure mode (1-10)
IVENO1 (10)	Curve numbers for first phase of 10 failure modes
IVENO2 (10)	Curve numbers for second phase of 10 failure modes
MODTYP (10)	Mode for each failure mode 1 ⇒ one phase 2 ⇒ two phases
IALPHA	Curve number for α computation
IBETAC	Curve number for β computation
IGAMM1	Curve number for γ_1 computation
IGAMM2	Curve number for γ_2 computation
IRFRB	Refurbish cycle number

ICYC	Index of mission number in cyclic mode
ICYCM1	ICYC-1
JDEL1	Step for mission print before the JMAX1 mission
JMAX1	Limit for use of previous print mission step
JDEL2	Step for mission print after JMAX1 mission
IREAD	File number of unit on which previous PROD is kept
IWRITE	File number of unit on which current PROD is written

FLOW CHARTS

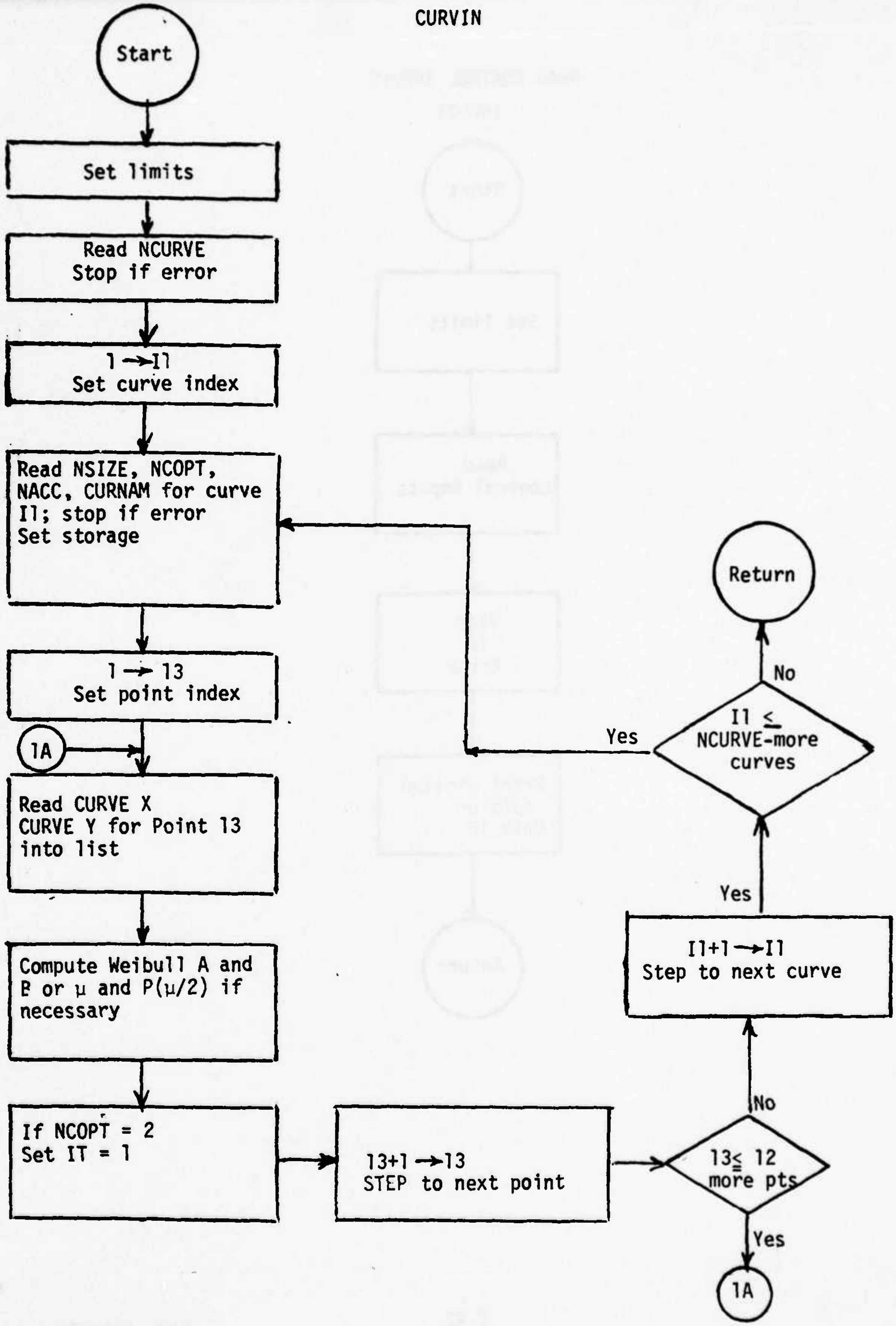
RELIABILITY MODEL

MAIN PROGRAM
MAIN



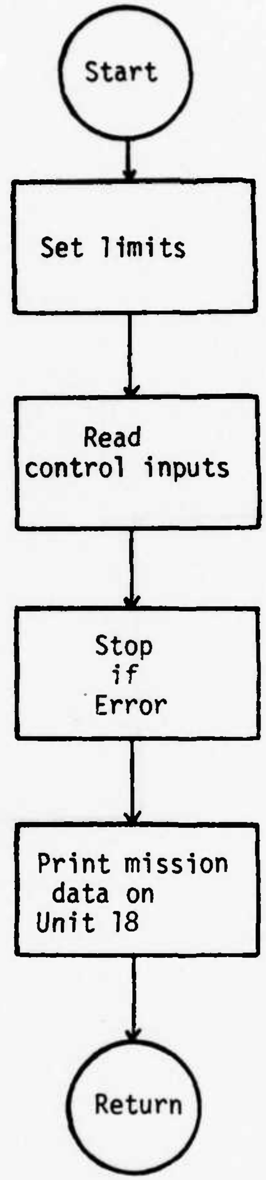
READ CURVE INPUTS

CURVIN



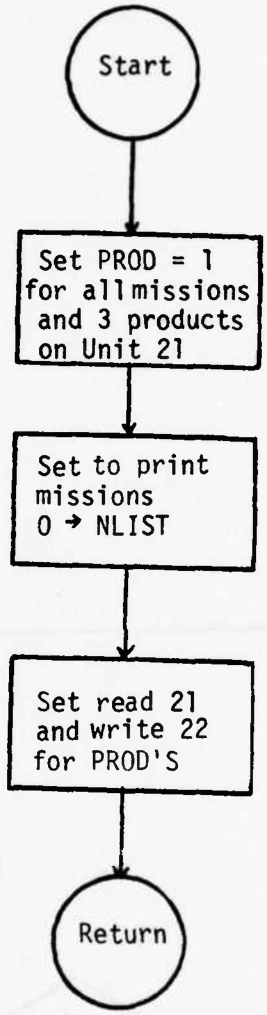
READ CONTROL INPUTS

INPUT1



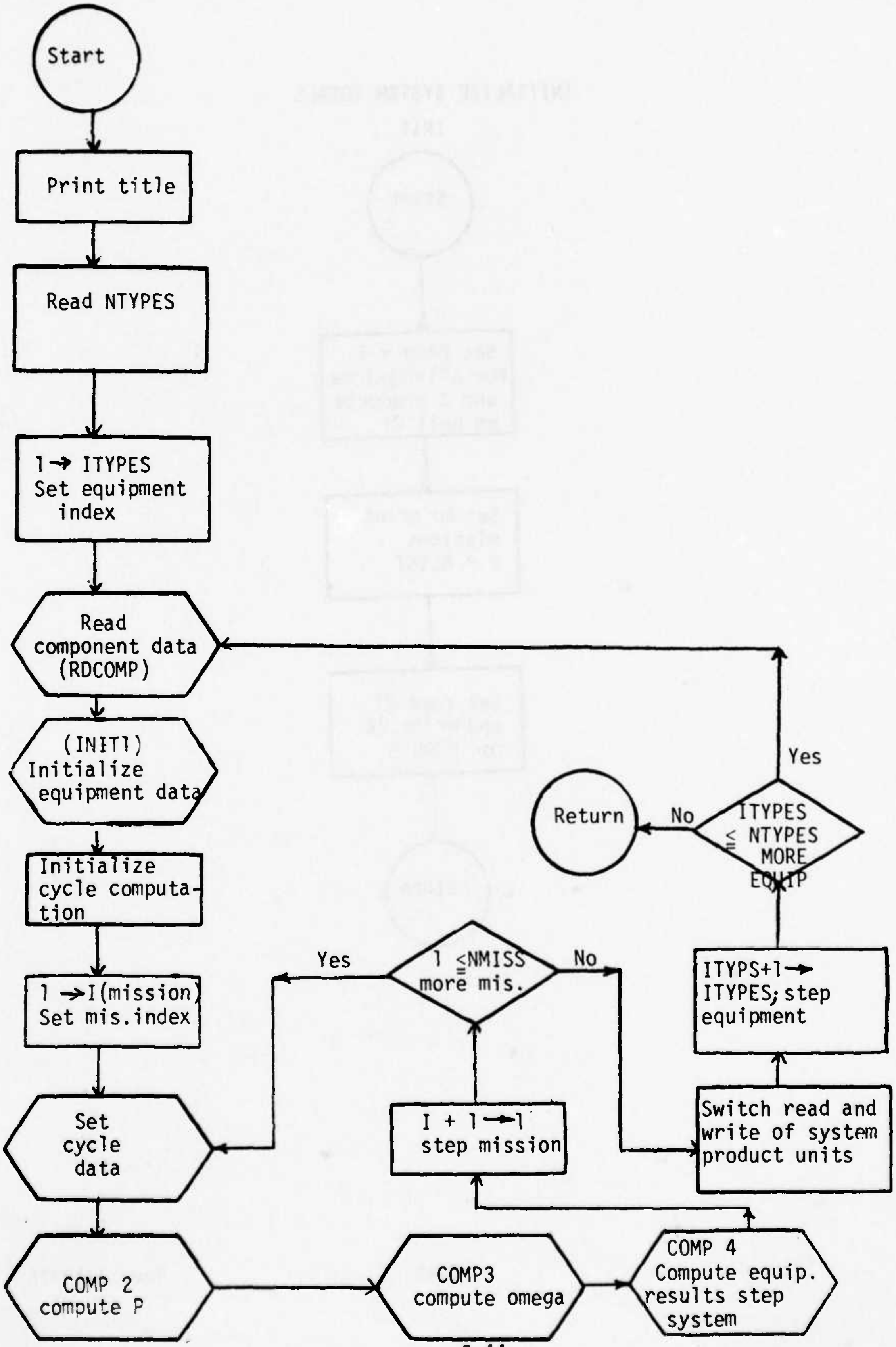
INITIALIZE SYSTEM TOTALS

INIT



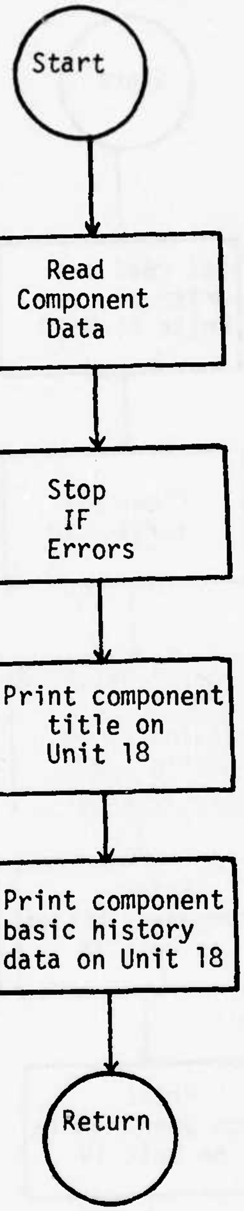
CONTROL FOR COMPUTATION

COMP



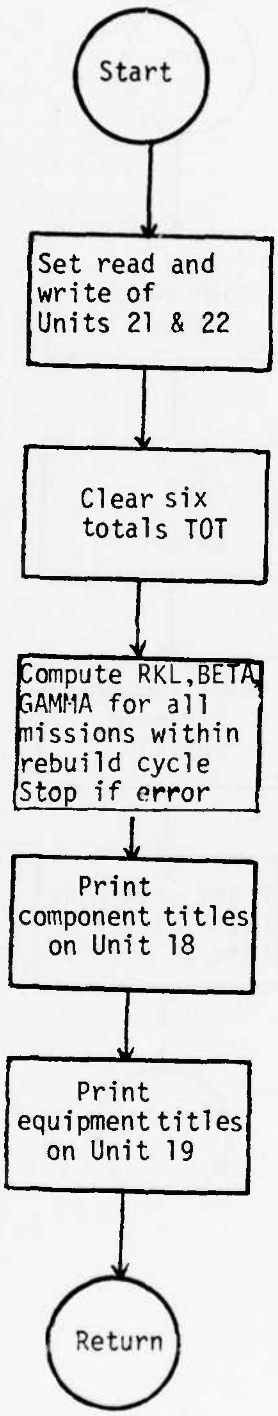
READ COMPONENT DATA

RDCOMP



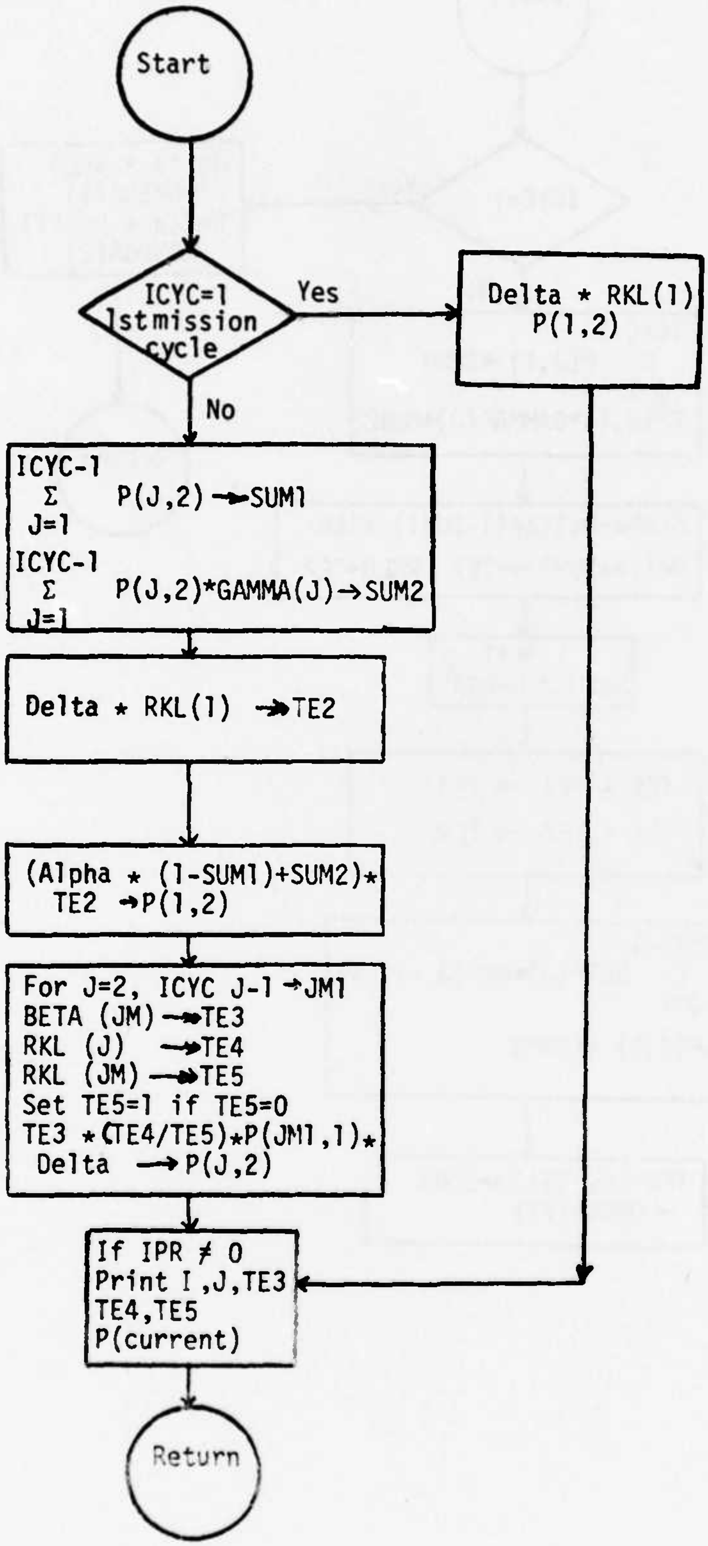
INITIALIZE EQUIPMENT TOTALS
AND PRECOMPUTE CURVE DATA

INIT1



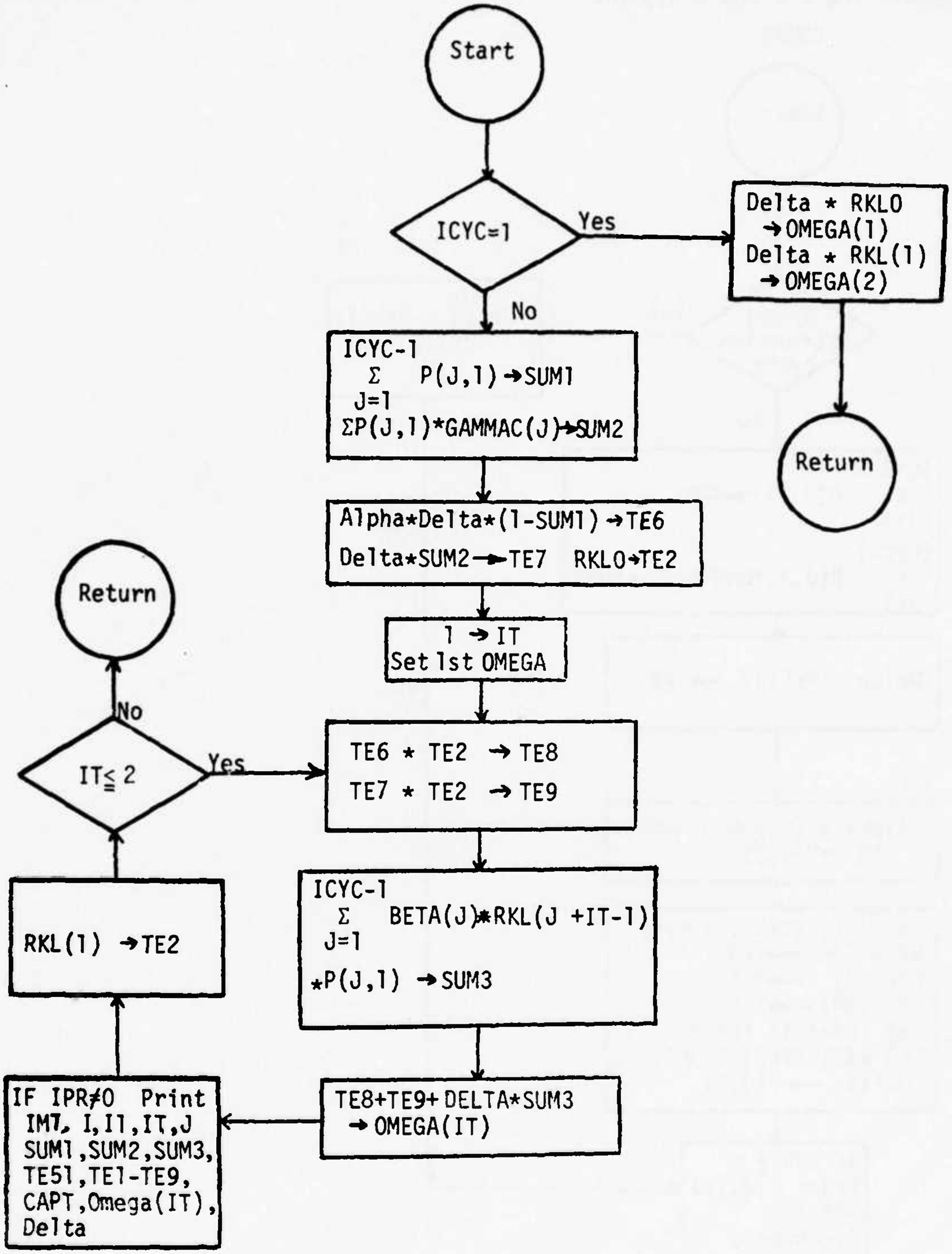
COMPUTE THE P's FOR A MISSION

COMP2



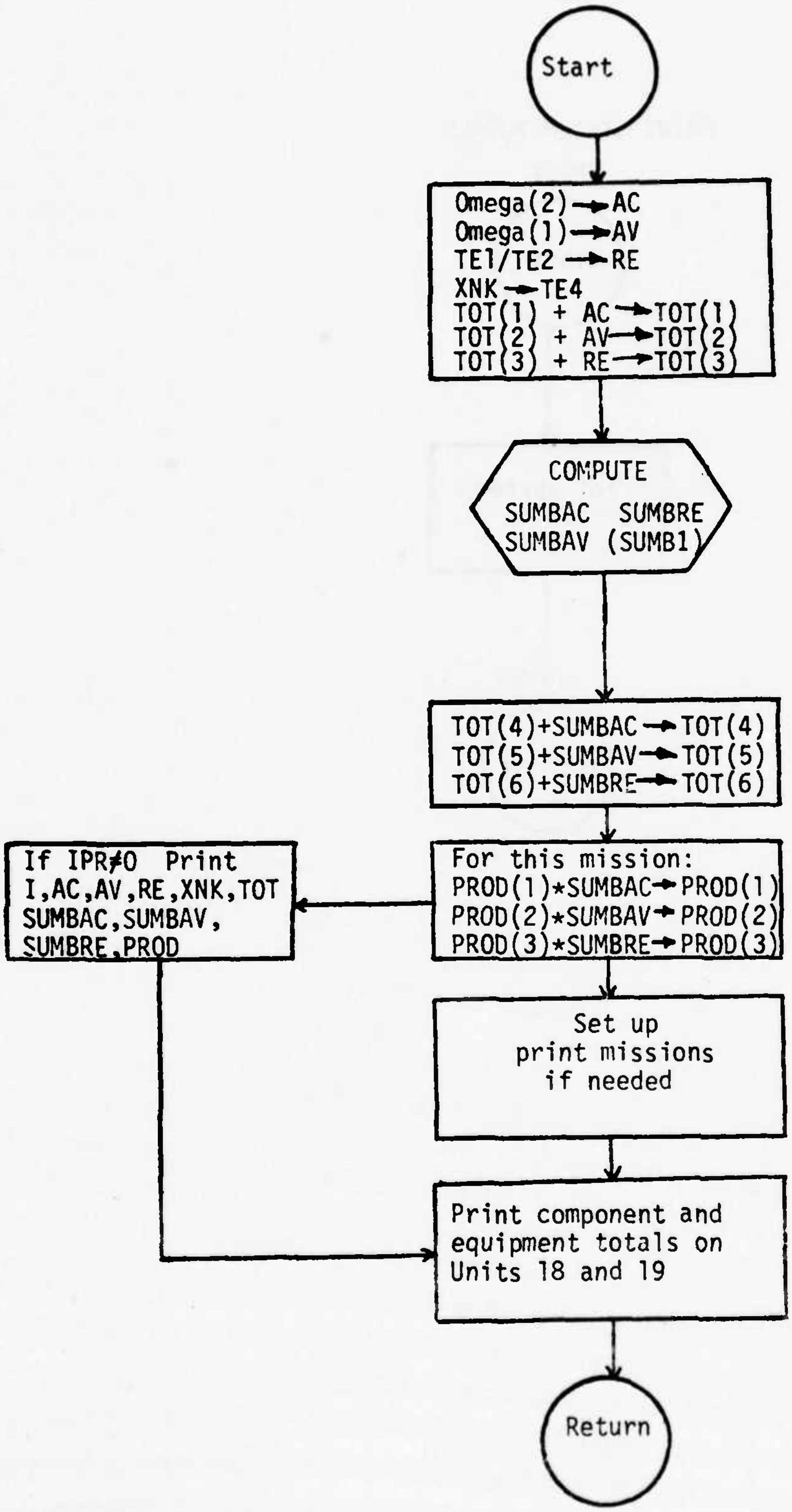
COMPUTE OMEGAS FOR A MISSION

COMP3

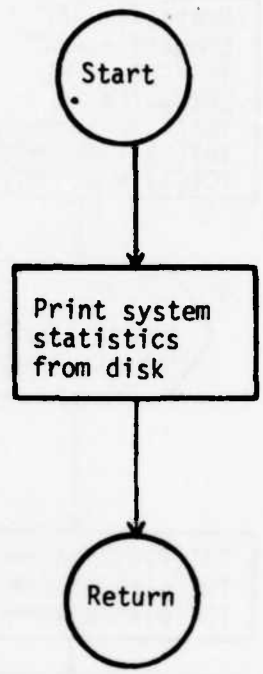


COMPUTE EQUIPMENT STATISTICS FOR A MISSION

COMP4

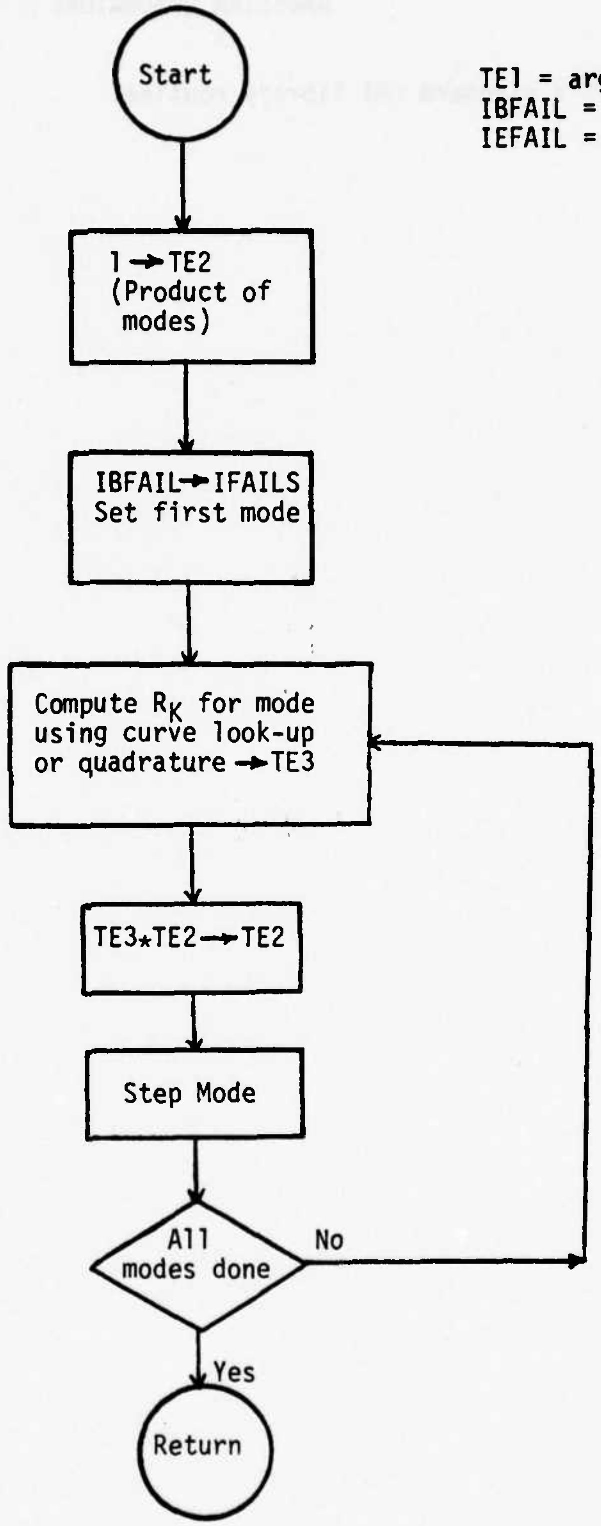


PRINT SYSTEM TOTALS
PRTOT



COMPRK (TE1, IBFAIL, IEFAIL)
COMPUTE R_K FOR A SET OF MODES

TE1 = argument
IBFAIL = index 1st mode
IEFAIL = index last mode



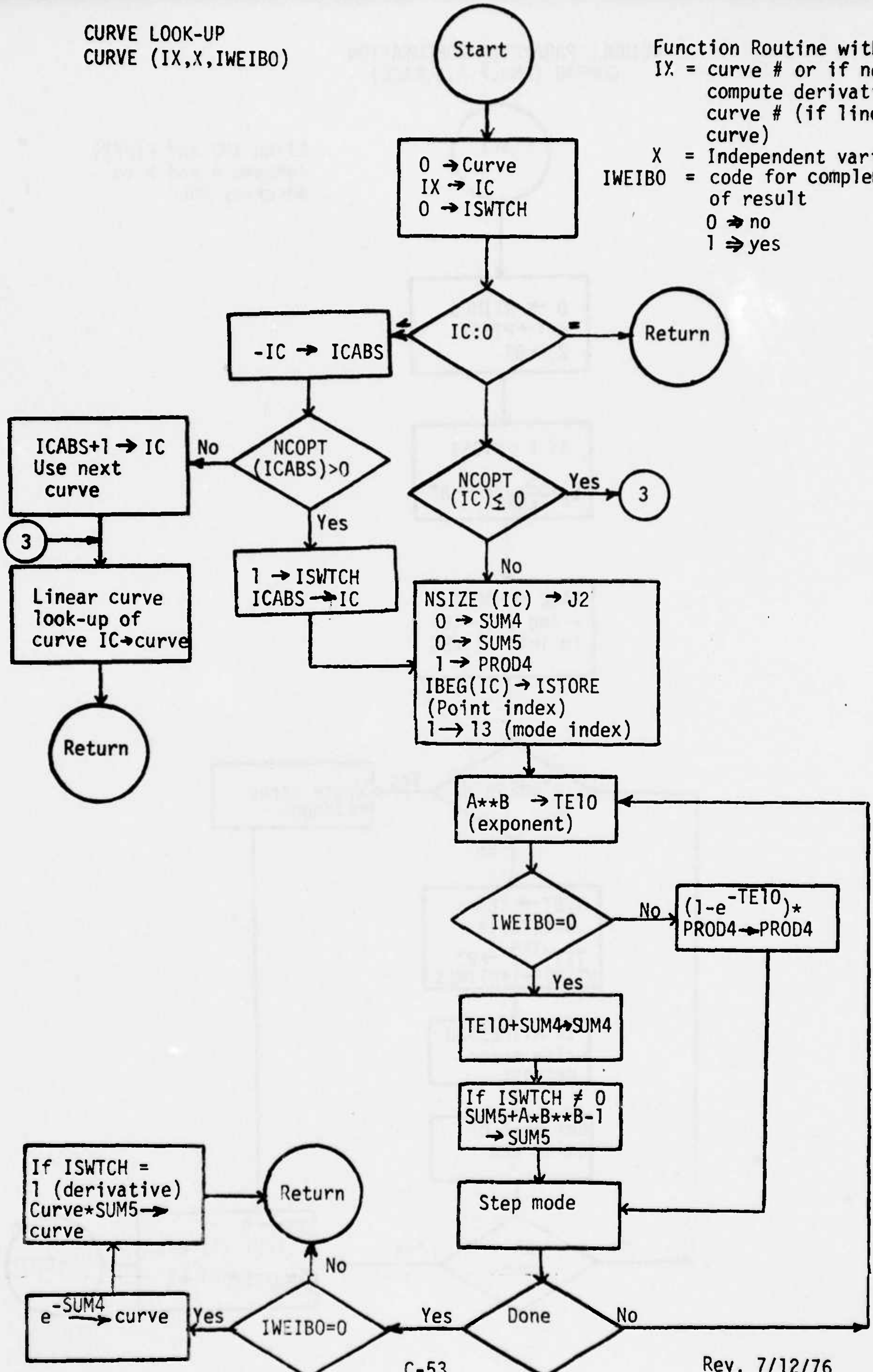
AUGUS (A,B,R,S,J,F,CP)

GAUSSIAN QUADRATURE

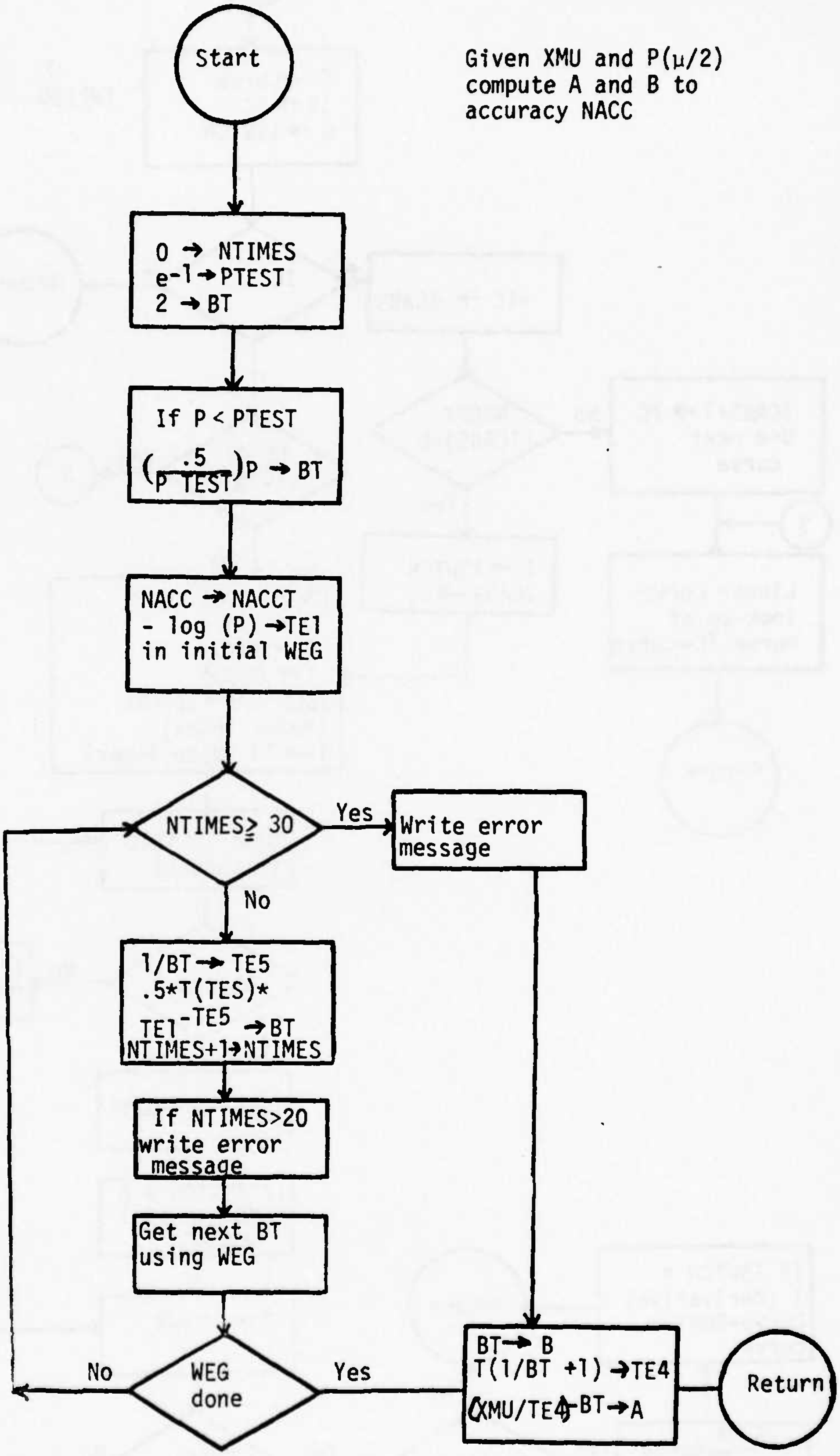
This is a standard ORI library routine.

CURVE LOOK-UP
CURVE (IX,X,IWEIBO)

Function Routine with
IX = curve # or if negative compute derivative of curve # (if linear next curve)
X = Independent variable
IWEIBO = code for complement of result
0 → no
1 → yes

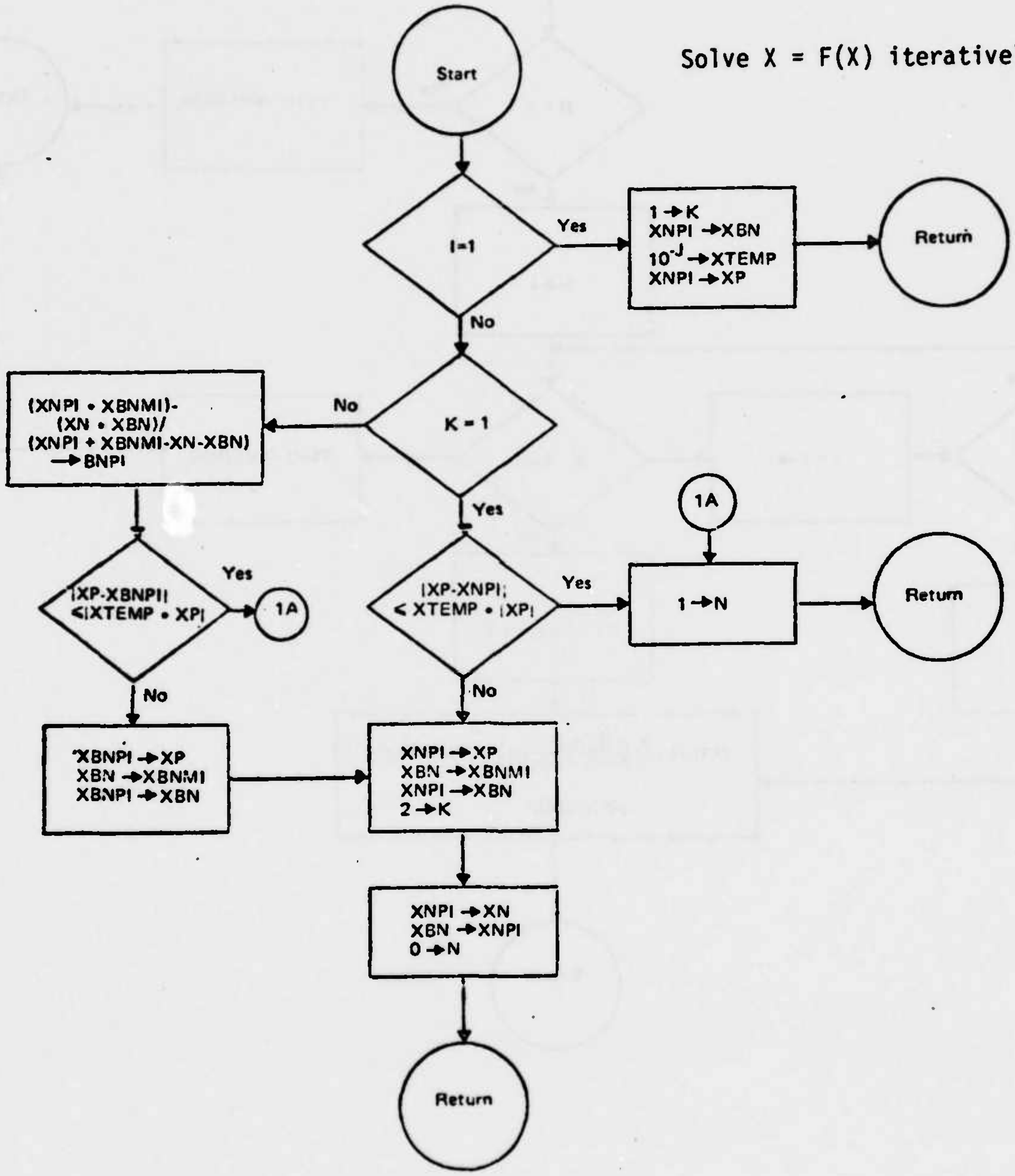


WEIBULL PARAMETER COMPUTATION
COMPAB (XMU,P,A,B,NACC)

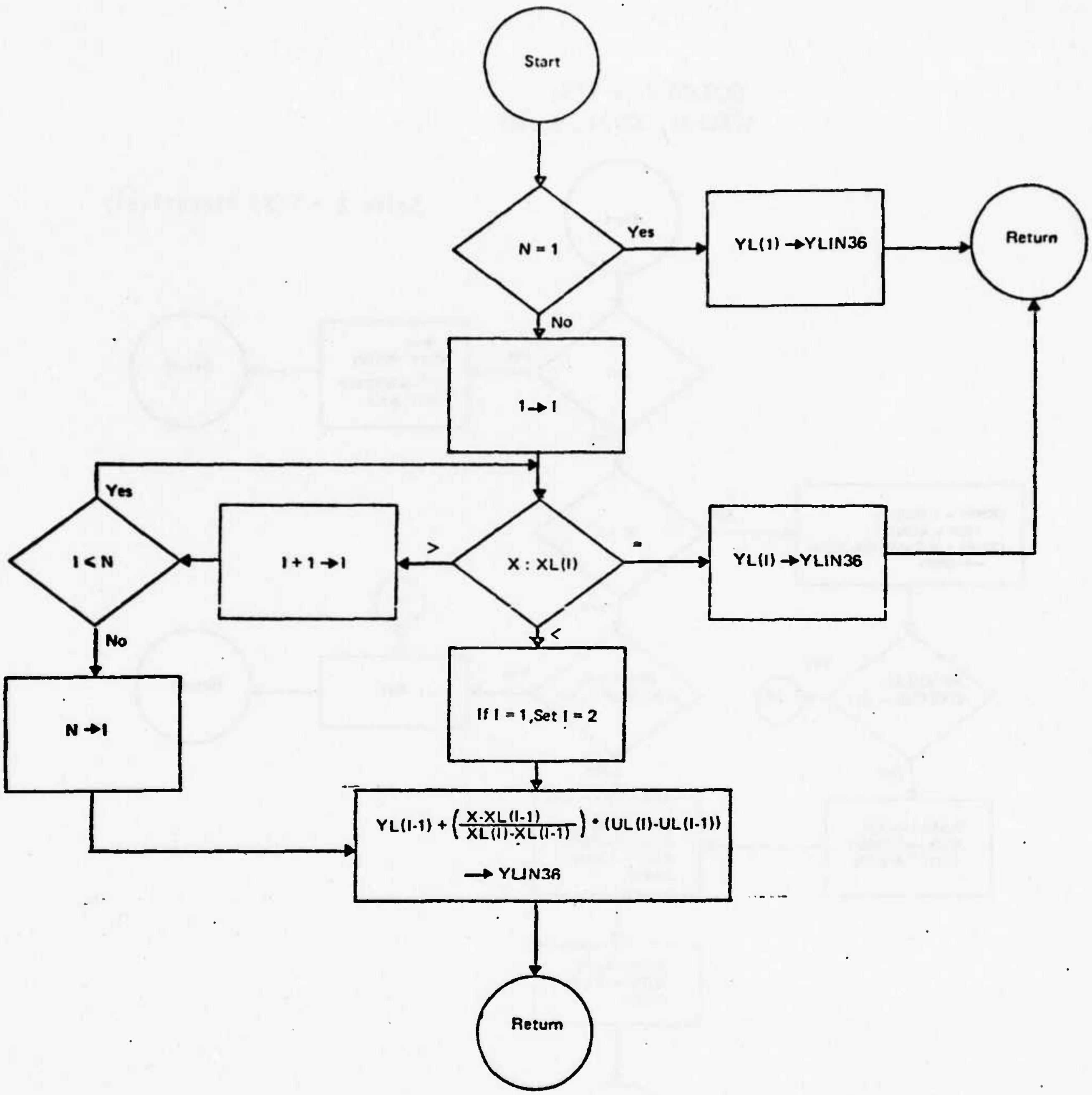


SOLVE X = F(X)
WEG (I, XNP1, J, N)

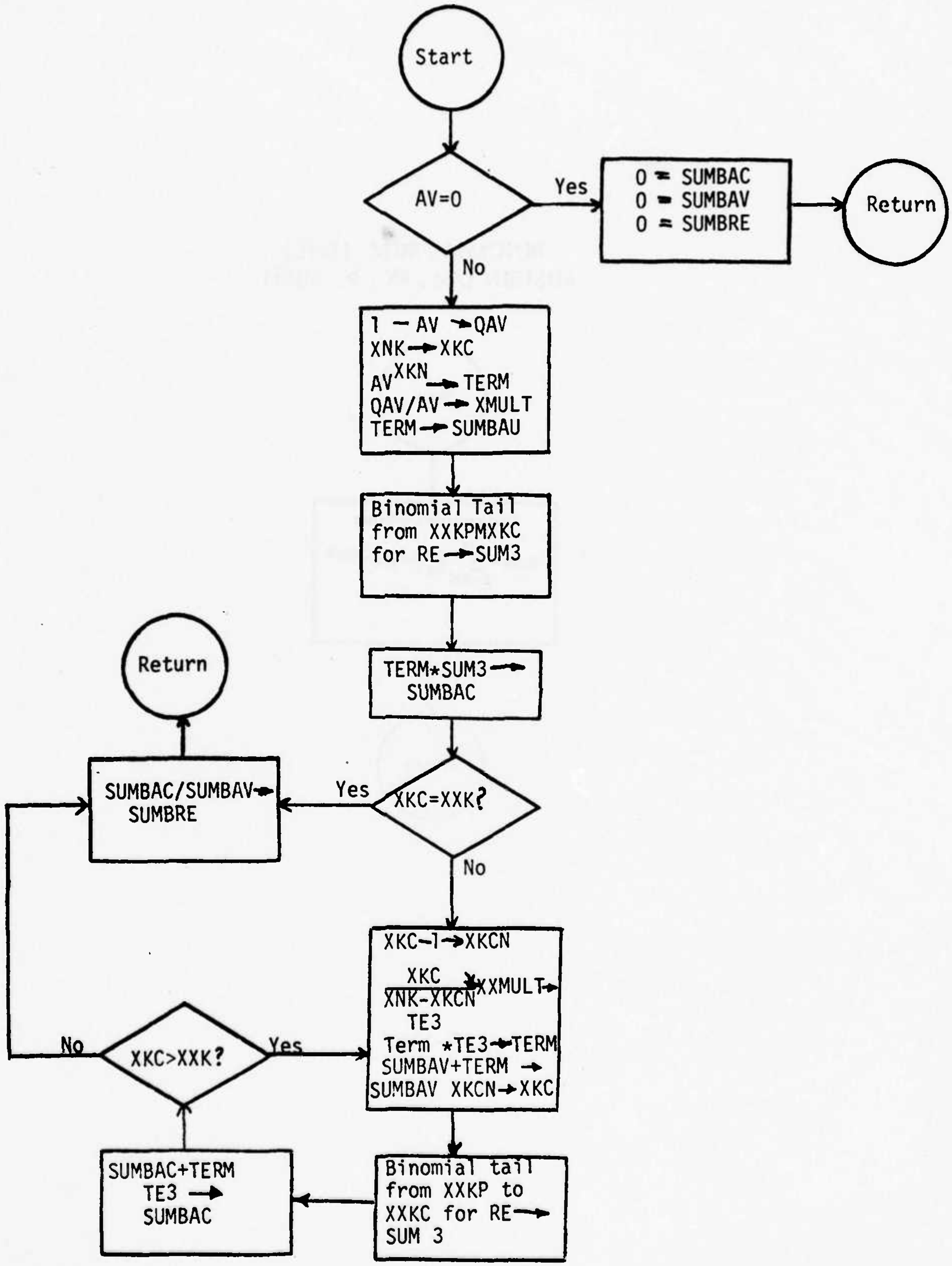
Solve X = F(X) iteratively



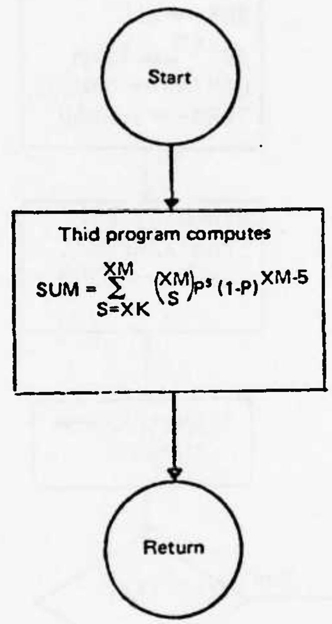
LINEAR CURVE LOOK-UP
YLIN36 (N, XL, YL, X)



SUMB1
COMPUTATION OF EQUIPMENT AVAILABILITY AND ACCOMPLISHMENT



BINOMIAL SUM (TAIL)
SUMBIN (XM, XK, P, SUM)



PROGRAM LISTINGS

```
              C        MAIN PROGRAM VERSICN 3 REVISED RELIABILITY MODEL      ZUSPAN/COOK
              C                   UNE MISSION TYPE ONLY
              C                          12/11/75
 0001               IMPLICIT REAL * 4(A-H,O-Z)
              C        CURVE INPUTS   FROM UNIT 9
 0002               CALL CURVIN
              C     MAIN INPUTS
              C             READ SYSTEM AND MISSICN CATA
 0003             1 CALL INPUT1
              C           INITIALIZE SYSTEM PRODUCTS
 0004               CALL INIT
              C         CONTROL FOR COMPUTATION FOR ALL TYPES AND MISSIONS
 0005               CALL COMP
              C         COMPUTE AND PRINT SYSTEM TOTALS
 0006               CALL PRTOT
 0007               GOTO 1
 0008               END
```

```
0001          SUBROUTINE CURVIN
          C                    READ INPUT CURVES FROM UNIT 9
0002          IMPLICIT REAL * 4 (A-H,O-Z)
0003          COMMON T,TAU,XMAR
0004          COMMON CURVEX(400),CURVEY(400(,POINAM(10,400),CURNAM(10,100(
0005          COMMON WE(BA(400),WE(BB(400)
0006          COMMON PROD(3),TOT(6)
0007          COMMON XNK,XXK,XXKP
0008          COMMON ALPHA,RHO,DELTA,UNIT(5(,SUMT,          CAPT,DELTT,XIT
0009          COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2(
0010          COMMON AC,AV,RE
0011          COMMON RHOT,RKL(100 ),BETA(100 ),XAMMA(100 (,P(100 ,2)
0012          COMMON RKLO,SSLIFE,EPS,GAMMA2
0013          COMMON ITLE(20),NM(SS,ICPT1,NTYPES,IPR,    NLIST,MLIST(500),MSTART
0014          COMMON MISNAM(10),M(SDES(20,5)
0015          COMMON I,(MI,(TYPES
0016          COMMON NCURVE,NSIZE(100(,NCCPT(100(,NACC(100)
0017          COMMON IBEG(100(,IENAME(4(,ICNAME(4(
0018          COMMON NFAILS,IVENO1(10(,(VENO2(10(,MODTYP(10(
0019          COMMON (ALPHA,IBETAC,(GAMM1,(GAMM2
0020          COMMON IRFRB,(CYC,(CYCM1,JDEL1,JMAX1,JDEL2
0021          COMMON IREAD,(WRITE,(FUNAM(4)
0022          XMAX1 = .15
0023          (MAX3 = 100
0024          (ERR = 0
0025          ISTORE = 0
0026          (STOMX = 400
0027          READ (9,101,END=96) NCURVE
0028          WRITE (6,201) NCURVE
0029          (F (NCURVE - IMAX3(  11,11,99
0030        11 CONTINUE
0031          DO 1 I1=1,NCURVE
0032          READ (9,102( NSIZE((1(,NCOPT(I1(,NACC((1(,ICURNAM(K,(1),K=1,10)
0033          WRITE (6,202( (1,NSIZE((1),NCOPT((1),NACC((1(,
             *   (CURNAM(K,I1(,K=1,10(
0034          IC2 = NCOPT(I1(
0035          IF ((C2 .LT. 0 .OR. (C2 .GT. 2)  GO TO 95
0036          NACD = NACC((1)
0037          I2 = NS(ZE(I1)
0038          ITEST = ISTORE + (2
0039          (F ((TEST .GT. (STOMX(  GO TO 98
0040          (BEG((1( = (STORE + 1
0041          DO 2 I3=1,I2
0042          ISTORE = ISTORE + 1
0043          READ (9,103) CURVEX((STORE),CURVEY((STORE),(POINAM(K,(STORE),
             *  K=1,10(
0044          WRITE (6,203) I3,(STORE,CURVEX(ISTORE(,CURVEY((STORE),
             *   (POINAM(K,(STORE(,K=1,10)
0045          IF ((C2(  ,,2,3
0046         3 CONTINUE
0047          (F ((C2 .EQ. 1)  GO TO 31
0048          NCOPT((1) = 1
0049          WE(BA(ISTORE( = CURVEX((STORE(
0050          WE(BB(ISTORE) = CURVEY(ISTORE)
0051          TF1 = (1./WE(BB((STORE)( + 1.
0052          TF2 = GAMMA(TL1)
```

```
      CURVEX(ISTORE) =TE2*(WEIBA(ISTORE)**(-1./WEIBB(ISTORE)))
      CURVEY(ISTORE) =EXP(-((TE2/2.)**WEIBB(ISTORE)))
      WRITE (6,205) CURVEX(ISTORE),CURVEY(ISTORE)
      GO TO 2
   31 CONTINUE
      IF (CURVEY(ISTORE) - XMAX1)  97,13,13
   97 WRITE (6,303) CURVEY(ISTORE),XMAX1
      IERR = IERR + 1
   13 CONTINUE
      IF (CURVEY(ISTORE) .NE. .60656)  GO TO 21
      WEIBA(ISTORE) = 1./CURVEX(ISTORE)
      WEIBB(ISTORE) = 1.
      GO TO 22
   21 CONTINUE
      CALL COMPAB(CURVEX(ISTORE),CURVEY(ISTORE),WEIBA(ISTORE),
     *    WEIBB(ISTORE),NACD)
   22 CONTINUE
      WRITE (6,204) WEIBA(ISTORE),WEIBB(ISTORE)
    2 CONTINUE
    1 CONTINUE
      IF (IERR .GT.  0)  STOP
      RETURN
   99 WRITE (6,301) NCURVE,IMAX3
      STOP
   95 WRITE (6,305)
      STOP
   98 WRITE (6,302) ISTOMX
      STOP
   96 WRITE (6,304)
      STOP
  101 FORMAT (I10)
  102 FORMAT (I10,I10,I10,10X,10A4)
  103 FORMAT (10X,2F10.0,10X,10A4)
  201 FORMAT (7H1NCURVE,I10)
  202 FORMAT (6H0CURVE,I5,5X,6HNSIZE=,I5,5X,6HNCOPT=,I5,5X,5HNACC=,
     *    I5,5X,10A4)
  203 FORMAT (10X,5HPOINT,I5,2X,6HISTORE,I5,2X,7HCURVEX=,G16.8,2X,
     *    7HCURVEY=,G16.8,2X,10A4)
  204 FORMAT (25X,2HA=,G16.8,10X,2HB=,G16.8)
  205 FORMAT (25X,3HMU=,G16.8,10X,8HP(MU/2)=,G16.8/
     *    1X,2I5,5G16.8)
  301 FORMAT (15H0NCURVE TOO BIG,2I10)
  302 FORMAT (19H0NO ROOM FOR CURVES,I10)
  303 FORMAT (12H0B TOO SMALL,2G16.8)
  304 FORMAT (14H0NO CURVE DATA/)
  305 FORMAT (19H0NCOPT OUT OF RANGE/)
      END
```

```
      SUBROUTINE INPUT1
C              MAIN INPUTS
C                   TITLE AND MISSION DATA
      IMPLICIT REAL * 4 (A-H,O-Z)
      COMMON T,TAU,XMAR
      COMMON CURVEX(400),CURVEY(400),PCINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON PROD(3),TOT(6)
      COMMON XNK, XXK, XXKP
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,           CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
      COMMON AC,AV,RE
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100 ),P(100 ,2)
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON ITLE(20),NMISS,IOPT1,NTYPES,IPR,   NLIST,MLIST(500),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),ICNAME(4)
      COMMON NFAILS,IVENO1(10),IVENO2(10),MODTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IRFRB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      IMAX1 = 100
      READ (5,101,END=99) (ITLE(M),M=1,19),IPR
      WRITE (6,201) (ITLE(M),M=1,19),IPR
      READ  (5,102)  NMISS,T,  TAU,EPS,   (MISNAM(K),K=1,10)
      NT = 2
      WRITE (6,202)  NMISS,T,  TAU, EPS,  (MISNAM(K),K=1,10(
      IF (NMISS - IMAX1)  11,11,98
   11 CONTINUE
      SSLIFE = NMISS * (T+TAU)
      XMAR = NMISS/SSLIFE
      READ (5,107)  ((MISDES(K,J),K=1,20),J=1,5)
      WRITE (6,207) ((MISDES(K,J),K=1,20),J=1,5)
      READ (5,103)   JDEL1,JMAX1,JDEL2
      WRITE (6,203)  JDEL1,JMAX1,JDEL2
C              PRINT SYSTEM AND MISSION SUMMARY FOR REPORT 18
      WRITE (18,501) (ITLE(M(,M=1,19)
      WRITE (18,502) (MISNAM(K(,K=1,10),NMISS,T,TAU
      WRITE (18,503) SSLIFE
      WRITE (18,504) XMAR
      WRITE (18,505) ((MISDES(K,J),K=1,20),J=1,5)
      RETURN
   99 STOP
   98 WRITE (6,301) NMISS,IMAX1
      STOP
   97 WRITE (6,302) NLIST, IMAX1
      STOP
  101 FORMAT (19A4,I4)
  102 FORMAT (I5,F5.0,    F5.0,F10.0,15X,10A4)
  103 FORMAT (4I5)
  104 FORMAT (5F10.0)
  106 FORMAT (F10.0)
  107 FORMAT (20A4)
  201 FORMAT (36HIVERSION 3 REVISED RELIABILITY MODEL//10X,19A4,5X,
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FORTRAN IV G LEVEL  21              INPUT1              DATE = 76257          18/06/37              PAGE 0002
                          *    4HIPR=,I5/)
 0054             202 FORMAT 17H NMISS=,I5,5X,2HT=,F10.3,
                          1                          5X,4HTAU=,F10.3,1X,
                          3     4HEPS=,F12.8,1X,7HMISNAM=,10A4)
 0055             203 FORMAT(26HOMISSION PRINT RESULT DATA,1X,7H JDEL1=,I5,7H JMAX1=,
                          *    I5,7H JDEL2=,I5)
 0056             204 FORMAT (8H MISSION,8X,1HT,7X/(I8,G16.8))
 0057             206 FORMAT (8H SSLIFE=,F10.1)
 0058             207 FORMAT (7HOMISDES/(20X,20A4))
 0059             301 FORMAT (14HOMMISS TOO BIG,2I10)
 0060             302 FORMAT (14HONLIST TOO BIG,2I10)
 0061             304 FORMAT (18HONLIST REDUCED BY ,I10)
 0062             501 FORMAT (1H1,50X,36HAMSEC SYSTEM AND MISSION DESCRIPTION//
                          *    25X,19A4/)
 0063             502 FORMAT (1HO,4X,12HMISSION NAME,38X,10A4/
                          1   1HO,4X,18HNUMBER OF MISSIONS,32X,I10/
                          2   1HO,4X,21HMISSION LENGTH(HOURS),29X,F10.2/
                          3   1HO,4X,21HTIME BETWEEN MISSIONS,29X,F10.2)
 0064             503 FORMAT (1HO,4X,33HSYSTEM SERVICE LIFE (CLOCK HOURS),17X,F10.2)
 0065             504 FORMAT (1HO,4X,42HMISSION ARRIVAL RATE (MISSION/CLOCK HOURS),
                          *   8X,F10.3)
 0066             505 FORMAT (1HO,4X,20A4)
 0067                 END
```

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FORTRAN IV G LEVEL  21                INIT               DATE = 76257        18/06/37              PAGE 0001

 0001                 SUBROUTINE INIT
             C             INITILIAZE SYSTEM TOTALS AND PRINT OF RESULTS
 0002                 IMPLICIT REAL * 4 (A-H,C-Z)
 0003                 COMMON T,TAU,XMAR
 0004                 COMMON CURVEX(400),CURVEY(400),PUINAM(10,400),CURNAM(10,100)
 0005                 COMMON WEIBA(400),WEIBB(400)
 0006                 COMMON PROD(3),TOT(6)
 0007                 COMMON XNK,XXK,XXKP
 0008                 COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
 0009                 COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
 0010                 COMMON AC,AV,RE
 0011                 COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100 ),P(100 ,2)
 0012                 COMMON RKLO,SSLIFE,EPS,GAMMA2
 0013                 COMMON ITLE(20),NMISS,IOPT1,NTYPES,IPR,    NLIST,MLIST(500),MSTART
 0014                 COMMON MISNAM(10),MISDES(20,5)
 0015                 COMMON I,IM1,ITYPES
 0016                 COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
 0017                 COMMON IBEG(100),IENAME(4),ICNAME(4)
 0018                 COMMON NFAILS,IVEND1(10),IVEND2(10),MODTYP(10)
 0019                 COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
 0020                 COMMON IRFRB,ICYC,ICYCM1,JOEL1,JMAX1,JOEL2
 0021                 COMMON IREAD,IWRITE,IFUNAM(4)
 0022                 REWIND 21
 0023                 OC 2 J=1,3
 0024               2 PROD(J) = 1.
 0025                 DO 1 I=1,NMISS
 0026                 WRITE (21)  I,PROD
 0027               1 CONTINUE
 0028                 NLIST = 0
 0029                 REWIND 21
 0030                 IREAD = 21
 0031                 IWRITE = 22
 0032                 REWIND 22
 0033                 RETURN
 0034                 END
```

```
FORTRAN IV G LEVEL  21                COMP              DATE = 76257          18/06/37                PAGE 0001
 0001                 SUBROUTINE COMP
               C         CONTROL FOR COMPUTATION FOR ALL TYPES AND MISSIONS
 0002                 IMPLICIT REAL * 4 (A-H,O-Z)
 0003                 COMMON T,TAU,XMAP
 0004                 COMMON CURVEX(400),CURVEY(400),PD(NAM(10,400),CURNAM(10,100)
 0005                 COMMON WEIBA(400),WEIBB(400)
 0006                 COMMON PROD(3),TOT(6)
 0007                 COMMON XNK,XXK,XXKP
 0008                 COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,         CAPT,DELTT,XIT
 0009                 COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
 0010                 COMMON AC,AV,RE
 0011                 COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100 ),P(100 ,2)
 0012                 COMMON RKLO,SSLIFE,EPS,GAMMA2
 0013                 COMMON ITLE(20),NMISS,IOPT1,NTYPES,IPR,   NLIST,MLIST(500),MSTART
 0014                 COMMON MISNAM(10),MISDES(20,5)
 0015                 COMMON I,IM1,ITYPES
 0016                 COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
 0017                 COMMON IBEG(100),IENAME(4),ICNAME(4)
 0018                 COMMON NFAILS,IVEND1(10),IVEND2(10),MODTYP(10)
 0019                 COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
 0020                 COMMON IRFRB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
 0021                 COMMON IREAD,IWRITE,IFUNAM(4)
 0022                 WRITE (6,200) (ITLE(M),M=1,19)
 0023                 READ (5,101) NTYPES
 0024                 WRITE (6,201) NTYPES
 0025                 DO 1  ITYPES=1,NTYPES
 0026                 CALL RDCOMP
               C           INITIALIZE EQUIPMENT  TOTALS
 0027                 CALL INIT1
 0028                 ICYC = 0
 0029                 DO 2 I=1,NMISS
 0030                 IM1 = I - 1
 0031                 ICYC = ICYC + 1
 0032                 IF (ICYC .GT. IRFRB)  ICYC = 1
 0033                 ICYCM1 = ICYC - 1
               C         COMPUTE P FOR THIS EQUIPMENT-MISSION AND PREV, MISS.
 0034                 CALL COMP2
               C         COMPUTE OMEGAS FOR THIS EQUIPMENT-MISSION AND PREV. MISS.
 0035                 CALL COMP3
               C           COMPUTE EQUIPMENT RESULTS AND STEP SYSTEM RESULTS
 0036                 CALL COMP4
 0037               2 CONTINUE
               C         PRINT TOTALS    EQUIPMENT-MISSION
 0038                 IT1 = IREAD
 0039                 IREAD = IWRITE
 0040                 IWRITE = IT1
 0041               1 CONTINUE
 0042                 RETURN
 0043             101 FORMAT (I10)
 0044             200 FORMAT (1H1,19A4)
 0045             201 FORMAT (33H0NTYPES OF EQUIPMENTS/COMPONENTS=,I5)
 0046                 END
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0001          SUBROUTINE RDCOMP
0002          IMPLICIT REAL * 4 (A-H,O-Z)
0003          COMMON T,TAU,XMAR
0004          COMMON CURVEX(400),CURVEY(400),PDINAM(10,400),CURNAM(10,100)
0005          COMMON WEIBA(400),WEIBB(400)
0006          COMMON PROD(3),TOT(6)
0007          COMMON XNK,XXK,XXKP
0008          COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XLT
0009          COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
0010          COMMON AC,AV,RE
0011          COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100 ),P(100 ,2)
0012          COMMON RKLO,SSLIFE,EPS,GAMMA2
0013          COMMON ITLE(20),NMISS,IOPTL,NTYPES,IPR,    NLIST,MLIST(500),MSTART
0014          COMMON MISNAM(10),MISDES(20,5)
0015          COMMON I,IM1,LTYPES
0016          COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
0017          COMMON IBEG(100),IENAME(4),ICNAME(4)
0018          COMMON NFAILS,IVENO1(10),IVENO2(10),MODTYP(10)
0019          COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
0020          COMMON IRFRB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
0021          COMMON IREAD,IWRITE,IFUNAM(4)
0022          DIMENSION FRMU(6),FRMUNM(6)
0023          DATA FRMU/.25,.5,.75,1.,1.5,2./
0024          DATA FRMUNM/4H 1/4,4H 1/2,4H 3/4,4H     ,4H 3/2,4H  2 /
0025          READ (5,102) (IENAME(M),M=1,4),     XNK,XXK,XXKP,IFUNAM
0026          WRITE (6,202) ITYPES,(IENAME(M),M=1,4),XNK,XXK,XXKP,IFUNAM
0027          IF (XNK.LT.0..OR.XXK.LT.0..OR.XXKP.LT.0..OR.XXK.GT.XNK.OR.
             *   XXKP.GT.XXK)     GO TO 96
0028          READ (5,103) (ICNAME(M),M=1,4),NFAILS,RHO,IALPHA,IBETAC,IGAMM1,
             *   IGAMM2,DELTA,IRFRB,(UNIT(K),K=1,5)
0029          IF (IRFRB .LE. 0 .OR. IRFRB .GT. NMISS)  IRFRB=NMISS
0030          WRITE (6,203) LTYPES,(ICNAME(M),M=1,4),NFAILS,RHO,IALPHA,IBETAC,
             *    IGAMM1,IGAMM2,DELTA,IRFRB,(UNIT(K),K=1,5)
0031          IF (DELTA .GT. 1. .OR. DELTA .LT. 0.)  GO TO 95
0032          IF (IBETAC .GT. NCURVE .OR. IGAMM1 .GT. NCURVE .OR. IGAMM2 .GT.
             *   NCURVE .OR. IALPHA .GT. NCURVE)     GO TO 99
0033          IF (NFAILS .GT. 10 .OR. NFAILS .LT. 1)  GO TO 98
0034          READ (5,104) (MODTYP(IFAILS),IVENO1(IFAILS),IVENO2(IFAILS),
             *    IFAILS=1,NFAILS)
0035          WRITE(6,204) (MODTYP(IFAILS),IVENO1(IFAILS),IVENO2(IFAILS),
             *    IFAILS=1,NFAILS)
0036          DO 51  IFAILS=1,NFAILS
0037          IF (MODTYP(IFAILS) .LT. 1 .OR. MODTYP(IFAILS) .GT. 2 .OR.
             *   IVENO1(IFAILS) .LT. 0 .OR. IVENO1(IFAILS) .GT. NCURVE .OR.
             *   IVENO2(IFAILS) .LT. 0 .OR. IVENO2(IFAILS) .GT. NCURVE)
             *  GO TO 97
0038       51 CONTINUE
         C               READING THE EXTRA COST CARDS SATA
0039          DO 55  I=1,4
0040       55 READ (5,951) CK
0041          WRITE (18,401)
0042          WRITE (18,402) (IENAME(K),K=1,4),(ICNAME(K),K=1,4),IFUNAM,RHO,
             *  (UNIT(K),K=1,5)
0043          WRITE (18,403) XNK,XXK,XXKP
0044          WRITE (18,400)
0045          WRITE (18,404) NFAILS
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0046            DO 52  IFAILS=1,NFAILS
0047            IRKLC = IVENU1(IFAILS)
0048            XMU = 0.
0049            MODE = MUDTYP(IFAILS)
0050            WRITE (18,452) MODE,IFAILS
0051            ISWICH = 1
0052            XMU = 0.
0053            IF (MODE .NE. 2)  ISWICH = 0
0054            DO 53  ICVE=1,MODE
0055            WRITE (18,451) ICVE,IRKLC,(CURNAM(K,IRKLC),K=1,10)
0056            NPTS = NSIZE(IRKLC)
0057            IC2 = NCUPT(IRKLC) + 1
0058            ISTORE = IBEG(IRKLC)
0059            IF (NPTS .NE. 1)  ISWICH = 0
0060            DO 2  IPTS=1,NPTS
0061            GO TO (11,12   ),IC2
0062         11 CONTINUE
0063            WRITE (18,406) IPTS,(POINAM(K,ISTORE),K=1,10),CURVEX(ISTORE),
               *  CURVEY(ISTORE)
0064            GO TO 3
0065         12 CONTINUE
0066            WRITE (18,407) IPTS,(POINAM(K,ISTORE),K=1,10),WEIBA(ISTORE),
               *  WEIBB(ISTORE),CURVEX(ISTORE),CURVEY(ISTORE)
0067            XMU = XMU+CURVEX(ISTORE)
0068          3 CONTINUE
0069            ISTORE = ISTORE + 1
0070          2 CONTINUE
0071            IRKLC = IVENU2(IFAILS)
0072         53 CONTINUE
0073            IF (ISWICH .EQ. 0)  GO TO 52
0074            DO 61  I=1,6
0075            TE10 = FRMU(I) * XMU
0076            JFAILS = IFAILS
0077            TE11 = COMPR(TE10,JFAILS,JFAILS)
0078            WRITE (18,411) FRMUNM(I),TE10,TE11
0079         61 CONTINUE
0080         52 CONTINUE
0081            NPTS = NSIZE(IBETAC)
0082            IC2 = NCOPT(IBETAC) + 1
0083            ISTORE = IBEG(IBETAC)
0084            WRITE (18,504)  IBETAC,(CURNAM(K,IBETAC),K=1,10)
0085            DO 25 IPTS=1,NPTS
0086            GO TO (21,22   ),IC2
0087         21 CONTINUE
0088            WRITE (18,506) IPTS,(POINAM(K,ISTORE),K=1,10),CURVEX(ISTORE),
               *  CURVEY(ISTORE)
0089            GO TO 24
0090         22 CONTINUE
0091            WRITE (18,507) IPTS,(POINAM(K,ISTORE),K=1,10),WEIBA(ISTORE),
               *  WEIBB(ISTORE),CURVEX(ISTORE),CURVEY(ISTORE)
0092         24 CONTINUE
0093            ISTORE = ISTORE + 1
0094         25 CONTINUE
0095            NPTS = NSIZE(IGAMM1)
0096            IC2 = NCOPT(IGAMM1) + 1
0097            ISTORE = IBEG(IGAMM1)
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0098            WRITE (18,604)  IGAMM1,(CURNAMIK,IGAMM1),K=1,10)
0099            DO 45 IPTS=1,NPTS
0100            GO TO (41,42   ),IC2
0101         41 CONTINUE
0102            WRITE (18,606) IPTS,(POINAMIK,ISTORE),K=1,10),CURVEX(ISTORE),
               *    CURVEY(ISTORE)
0103            GO TO 44
0104         42 CONTINUE
0105            WRITE (18,607) IPTS,(POINAMIK,ISTORE),K=1,10),WEIBA(ISTORE),
               *    WEIBB(ISTORE),CURVEX(ISTORE),CURVEY(ISTORE)
0106         44 CONTINUE
0107            ISTORE = ISTORE + 1
0108         45 CONTINUE
0109            GAMMA2 = CURVE(IGAMM2,TAU,1)
0110            WRITE (18,614) GAMMA2,IGAMM2,(CURNAMIK,IGAMM2),K=1,10)
0111            DELTAP = 1.-DELTA
0112            WRITE (18,704) DELTAP
0113            ALPHA = CURVE (IALPHA,TAU,1)
0114            WRITE (18,804)  ALPHA,IALPHA,(CURNAMIK,IALPHA),K=1,10)
0115            WRITE (18,901) IRFRB
0116            RETURN
0117         99 WRITE (6,301) IBETAC,IGAMM1,IGAMM2,IALPHA,NCURVE
0118            STOP
0119         98 WRITE (6,302) NFAILS
0120            STOP
0121         97 WRITE (6,303) IFAILS
0122            STOP
0123         96 WRITE (6,304)
0124            STOP
0125         95 WRITE (6,305)
0126            STOP
0127        102 FORMAT (4A4,4X,3F10.0,17X,2A4,A3,A2)
0128        202 FORMAT (6H0EQUIP,I5,3X,4A4,5X,5H XNK=,F10.0,
               1   5X,4HXXK=,F10.0,5X,5HXXKP=,F10.0,
               2   18X,7H(FUNAM=,2A4,A3,1X,A2)
0129        103 FORMAT (4A4,4X,I5,F5.0,4I5,F5.0,I5,5A4)
0130        104 FORMAT (10I(1,I2,I2,1X))
0131        204 FORMAT (11H FAIL MODES,10(I4,I4,I4))
0132        203 FORMAT (5H COMP,I5,1X,4A4,2X,7HNFAILS=,I3,2X,4HRHU=,F7.4/29X,
               *   7H(ALPHA=,I3,2X,7H(BETAC=,I3,2X,7H(GAMM1=,I3,2X,7H(GAMM2=,
               *   I3,2X,6HDELTA=, F7.4,2X,6H(RFRB=,I5,
               *               2X,5HUNIT=,5A4)
0133        400 FORMAT (1H0,35X,10(1H*),30HCOMPONENT LIFE CHARACTERISTICS,10(1H*))
0134        401 FORMAT (1H1,35X,10(1H*),
               *               32HCOMPONENT/EQUIPMENT REQUIREMENTS,10(1H*)//)
0135        402 FORMAT (16H EQUIPMENT NAME  ,4A4,2X,15HCOMPONENT NAME  ,4A4,2X,
               *   13HFUNCTION CODE,1X,2A4,A3,1X,A2/30X,
               *  9HUTIL RATE,F7.4,2X,17H FAILURE ARGUMNT  , 5A4 )
0136        403 FORMAT (1H0,4X,33HNUMBER OF COMPONENTS IN EQUIPMENT,22X,F10.0/
               1   1H0,4X,46HNUMBER OF FUNCTIONING COMPONENTS REQUIRED FOR-/
               2   1H0,9X,17HMISSION READINESS,33X,F10.0/
               3   1H0,9X,17HMISSION SUCCESS  ,33X,F10.0/)
0137        404 FORMAT (
               1   1H0,4X,23HNUMBER OF FAILURE MODES,I10/)
0138        406 FORMAT (9X,5HPOINT,
               *            I5,2X,1X,10A4,1X, 6HL(NEAR       ,3X,4HIND=,F10.2,
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                 1    5X,5HPROB=,F7.4)
 0139          407 FORMAT (3X,5HPHASE,
                 *            I5,2X,2X,10A4,1X, 6HWEIBUL       ,3X,2HA=,E14.6,1X,
                 *    2HB=,F7.4,2X,3HMU=,F10.2,1X,8HP(MU/2)=,F7.4)
 0140          411 FORMAT (80X,A4,4H MU=,F20.4,5X,2HP=,F10.5)
 0141          451 FORMAT (6H STAGE,I5,5X,15HUSES CURVE NO. ,I5,10X,10A4)
 0142          452 FORMAT (26H NUMBER OF FAILURE STAGES=,I5,9H FOR MODE,I5)
 0143          504 FORMAT (1H0,30X,10(1H*),37HMAINTENANCE FREQUENCY CHARACTERISTICS,
                 *    10(1H*)/  1H0,4X,
                 *    65HPROBABILITY OF NO PREVENTIVE MAINTENANCE WITH COMPONENT USE(B
                 *ETA)/60X,16H USES CURVE NO. ,I5,1X,10A4)
 0144          506 FORMAT (9X,5HPOINT,
                 *            I5,2X,1X,10A4,1X, 6HLINEAR       ,3X,4HIND=,F10.2,
                 1    5X,5HPROB=,F7.4)
 0145          507 FORMAT (3X,5HPHASE,
                 *            I5,2X,2X,10A4,1X, 6HWEIBUL       ,3X,2HA=,E14.6,1X,
                 *    2HB=,F7.4,2X,3HMU=,F10.2,1X,8HP(MU/2)=,F7.4)
 0146          604 FORMAT (1H0,4X,75HPROBABILITY OF INITIATING PREVENTIVE MAINTENANCE
                 * WITH COMPONENT USE(GAMMA1)/
                 *    60X,15HUSES CURVE NO. ,I5,1X,10A4)
 0147          606 FORMAT (9X,5HPOINT,
                 *            I5,2X,1X,10A4,1X, 6HLINEAR       ,3X,4HIND=,F10.2,
                 1    5X,5HPROB=,F7.4)
 0148          607 FORMAT (3X,5HPHASE,
                 *            I5,2X,2X,10A4,1X, 6HWEIBUL       ,3X,2HA=,E14.6,1X,
                 *    2HB=,F7.4,2X,3HMU=,F10.2,1X,8HP(MU/2)=,F7.4)
 0149          614 FORMAT (1H0,4X,57HPROBABILITY OF COMPLETING PREVENTIVE MAINTENANCE
                 *(GAMMA2)=, F10.6/60X,
                 *                      16H USES CURVE NO. ,I5,1X,10A4)
 0150          704 FORMAT (1H0,4X,56HPROBABILITY OF HANDLING/TRANSPORTATION FAILURE(1
                 *-DELTA)=,F10.6/)
 0151          804 FORMAT (1H0,4X,82HPROBABILITY OF COMPLETING CORRECTIVE MAINTENANCE
                 * FOLLOWING MISSION FAILURE(ALPHA)=,F10.6/
                 *    60X,15HUSES CURVE NO. ,I5,1X,10A4)
 0152          901 FORMAT (1H0,4X,27HCOMPONENT REBUILDING CYCLE=,I5,
                 *         10H (MISSION))
 0153          951 FORMAT (13F6.0)
 0154          301 FORMAT (45H0(BETA) OR (GAMM1 OR (GAMM2 OR (ALPHA TOO BIG,5I10)
 0155          302 FORMAT (24H0NFAILS TOO BIG OR SMALL,I10/)
 0156          303 FORMAT (20H0BAD DATA FOR FAILS=,I10/)
 0157          304 FORMAT (26H0XNK,XXK,XXKP INCONSISTENT/)
 0158          305 FORMAT (10H0DELTA BAD/)
 0159              END
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      SUBROUTINE INITI
C         INITIALIZE EQUIPMENT TOTALS   OVER ALL MISSIONS
C                  AND PRECOMPUTE CURVE DATA
      IMPLICIT REAL * 4 (A-H,O-Z)
      COMMON T,TAU,XMAR
      COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON PROD(3),TOT(6)
      COMMON XNK,XXK,XXKP
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
      COMMON AC,AV,RE
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100 ),P(100 ,2)
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON ITLE(20),NMISS,IOPT1,NTYPES,IPR,   NLIST,MLIST(500),MSTART
      COMMON MISNAM(10),MISOFS(20,5)
      COMMON I,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),ICNAME(4)
      COMMON NFAILS,IVENO1(10),IVENO2(10),MODTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IRFRB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      REWIND 21
      REWIND 22
      MSTART = 1
      DO 1 M=1,6
      TOT(M ) = 0.
    1 CONTINUE
      RHOT = RHO * T
      TEI = 0.
      WRITE (18,803)
      DO 2  I=1,IRFRB
      TEI = TEI + RHOT
      IF (I .NE. 1 .AND. RKL(I-1) .LT.   EPS)  GO TO 5
      RKL(I) = CUMPRK(TEI,1,NFAILS)
      GO TO 6
    5 RKL(I) = 0.
    6 CONTINUE
      GAMMA(I) = ICURVE(IGAMM1,TEI,1)
      BETA(I) = CURVE(IBETAC,TEI,0)
      IF (GAMMA(I)+BETA(I) .GT. 1.)  GO TO 99
      GAMMA(I) = GAMMA(I) * GAMMA2
      TE2 = 1.-BETA(I)-GAMMA(I)
      IF (RKL(I) .NE. 0.)  WRITE (18,804) I,TEI,RKL(I),BETA(I),
     *     GAMMA(I),TE2
    2 CONTINUE
      RKLO = CUMPRK(0.,1,NFAILS)
      IF ((PR .NE. 0)  WRITE (16,402) ALPHA,RKLO
      WRITE (18,901) (ITLE(K),K=1,19)
      WRITE (18,902) (ICNAME(K),K=1,4),(FUNAM,RHO,(UNIT(K),K=1,5)
      WRITE (18,903)
      WRITE (19,951) (ITLE(K),K=1,19)
      WRITE (19,952) (ICNAME(K),K=1,4),(FUNAM,(IENAME(K),K=1,4),RHO,
     *  (UNIT(K),K=1,5)
      WRITE (19,953) XNK,XXK,XXKP
```

```
0053              WRITE (19,954)
0054              RETURN
0055           99 WRITE (6,301) I,GAMMA(I),BETA(I)
0056              STOP
0057          301 FORMAT (30H0GAMMA1+BETA GREATER THAN ONE ,I5,2F16.8)
0058          401 FORMAT (8H0INIT1-1,2I5,3G16.8)
0059          402 FORMAT (8H0INIT1-2,2G16.8)
0060          801 FORMAT (1H1,20X,19A4//
                *     10X,40HCOMPONENT LIFE AND SUPPORT DISTRIBUTIONS)
0061          803 FORMAT (1H0,29X,4X,22HPREVENTIVE MAINTENANCE/
                *             3X,7HMISSION,5X,5HUSAGE,2X,8HSURVIVAL,3X,7HNONE    ,
                *              2X,8HCOMPLETE,1X,10HINCOMPLETE/)
0062          804 FORMAT (I10,F10.2,4F10.6)
0063          901 FORMAT (1H1,20X,19A4//
                *    45X,28HCOMPONENT RESULTS VERSUS AGE)
0064          902 FORMAT (16H COMPONENT NAME ,4A4,2X,13HFUNCTION CODE,1X,2A4,A3,
                *    1X,A2,3X,
                *  9HUTIL RATE,F7.4,2X,17H FAILURE ARGUMNT , 5A4 )
0065          903 FORMAT (10H0 MISSION,10H    USAGE ,11(1H*),9H MISSION ,10(1H*),
                *    5X,11(1H*),9H AVERAGE ,10(1H*)/ 2X,
                *    10H  NUMBER  ,10X,10HACCCMPLSH ,10HREADINESS ,10HRELIABLTY ,5X,
                *    10HACCUMPLSH ,10HREADINESS , 9HRELIABLTY/)
0066          951 FORMAT (1H1,20X,19A4//
                *    45X,28HEQUIPMENT RESULTS VERSUS AGE)
0067          952 FORMAT (16H COMPCNENT NAME ,4A4,2X,
                *    13HFUNCTION CODE,1X,2A4,A3,2X,A2/30X,15HEQUIPMENT NAME ,4A4,2X,
                *  9HUTIL RATE,F7.4,2X,17H FAILURE ARGUMNT , 5A4 )
0068          953 FORMAT (1H0,4X,33HNUMBER OF COMPCNENTS IN EQUIPMENT,22X,F10.0/
                1    1H0,4X,46HNUMBER OF FUNCTIONING COMPONENTS REQUIRED FOR-/
                2    1H0,9X,17HMISSION READINESS,33X,F10.0/
                3    1H0,9X,17HMISSION SUCCESS  ,33X,F10.0/)
0069          954 FORMAT (10H0  MISSICN,10H    USAGE ,11(1H*),9H MISSION ,10(1H*),
                *    5X,11(1H*),9H AVERAGE ,10(1H*)/ 2X,
                *    10H  NUMBER  ,10X,10HACCCMPLSH ,10HREADINESS ,10HRELIABLTY ,5X,
                *    10HACCUMPLSH ,10HREADINESS , 9HRELIABLTY/)
0070              END
```

```
0001          SUBROUTINE COMP2
        C                  COMPUTE P(J,1)  P(J,2)  FOR ALL J
        C                FOR MISSION I
0002          IMPLICIT REAL * 4 (A-H,O-Z)
0003          COMMON T,TAU,XMAR
0004          COMMON CURVEX(400),CURVEY(400),PCINAM(10,400),CURNAM(10,100)
0005          COMMON WEIBA(400),WEIBB(400)
0006          COMMON PROD(3),TOT(6)
0007          COMMON XNK,XXK,XXKP
0008          COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
0009          COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
0010          COMMON AC,AV,RE
0011          COMMON RHUT,RKL(100 ),BETA(100 ),GAMMA(100 ),P(100 ,2)
0012          COMMON RKLO,SSLIFE,EPS,GAMMA2
0013          COMMON ITLE(20),NMISS,ICPT1,NTYPES,IPR,    NLIST,MLIST(500),MSTART
0014          COMMON MISNAM(10),MISDES(20,5)
0015          COMMON I,IM1,ITYPES
0016          COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
0017          COMMON IBEG(100),IENAME(4),ICNAME(4)
0018          COMMON NFAILS,IVENO1(10),IVENO2(10),MODTYP(10)
0019          COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
0020          COMMON IRFRB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
0021          COMMON IREAD,IWRITE,IFUNAM(4)
0022          IF (ICYC - 1)  2,1,2
0023        1 P(1,2) = DELTA * RKL(1)
0024          J = 0
0025          TE3 = 0.
0026          TE4 = 0.
0027          TE5 = 0.
0028          TE6 = 0.
0029          GO TO 8
0030        2 CONTINUE
0031          SUM1 = 0.
0032          SUM2 = 0.
0033          DO 3 J=1,ICYCM1
0034          TE1 = P(J,2)
0035          P(J,1) = TE1
0036          SUM1 = SUM1 + TE1
0037          TE7 = GAMMA(J)
0038          SUM2 = SUM2 + TE7 * TE1
0039        3 CONTINUE
0040          TE2 = RKL(1) * DELTA
0041          P(1,2) = IALPHA    * (1.  -SUM1) + SUM2) * TE2
0042          DO 6 J=2,ICYC
0043          JM1 = J-1
0044          IF (P(JM1,2) .GE. EPS)  GO TO 11
0045          P(J,2) = 0.
0046          GO TO 6
0047       11 CONTINUE
0048          TE3 = BETA(JM1)
0049          TE4 = RKL(J)
0050          TE5 = RKL(JM1)
0051          IF (TE5 .EQ. 0.   )  TE5 = 1.
0052          P(J,2) = TE3 * (TE4/TE5) * P(JM1,1) * DELTA
0053        6 CONTINUE
0054        8 IF (IPR .NE. 0)  WRITE (I6,401) I,J,TE3,TE4,TE5,    (P(J,2),J=1,I)
```


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```
          RETURN
      401 FORMAT(6H COMP2,2X,2I5,3G16.8/(18X,6G16.8))
          END
```

```
      SUBROUTINE COMP3
C        COMPUTE OMEGAS I WHERE I = I+1 ST MISSION
      IMPLICIT REAL * 4 (A-H,O-Z)
      COMMON T,TAU,XMAR
      COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON PROD(3),TOT(6)
      COMMON XNK,XXK,XXKP
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,           CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
      COMMON AC,AV,RE
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100 ),P(100 ,2)
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON ITLE(20),NMISS,IOPT1,NTYPES,IPR,   NLIST,MLIST(500),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
      COMMON IBEG(100),IENAME(5),ICNAME(4)
      COMMON NFAILS,IVEND1(10),IVEND2(10),MOOTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IRFRB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      IF (ICYC - 1)  3,1,3
    1 CONTINUE
      OMEGA(1) = DELTA * RKLO
      OMEGA(2) = DELTA * RKL(1)
    2 CONTINUE
      RETURN
    3 CONTINUE
      SUM1 = 0.
      SUM2 = 0.
      DO 5 J=1,ICYCM1
      TE1 = P(J,1)
      SUM1 = SUM1 + TE1
      TE10 = GAMMA(J)
      SUM2 = SUM2 + TE10 * TE1
    5 CONTINUE
      TE6 = ALPHA     * DELTA*(1.  -SUM1)
      TE7 = SUM2 * DELTA
      TE2 = RKLO
      DO 6 IT = 1,2
      TE8 = TE6 * TE2
      TE9 = TE7 * TE2
      SUM3 = 0.
      DO 7 J=1,ICYCM1
      TE3 = BETA(J)
      TE4 = RKL(J+IT-1)
      TE5 = RKL(J)
      IF (TE5 .EQ. 0.  )  TE5=1.
      SUM3 = SUM3 + TE3*(TE4/TE5) * P(J,1)
    7 CONTINUE
      OMEGA(IT) = TE8+TE9+DELTA*SUM3
      IF (IPR .NE. 0)  WRITE(6,401) IM1,I,    IT,J,SUM1,SUM2,SUM3,
     1  TE1,TE2,TE3,TE4,TE5,TE6,TE7,TE8,TE9.      OMEGA(IT),DELTA
      TE2 = RKL(1)
    6 CONTINUE
```

```
          RETURN
      401 FORMAT(6H CUMP3,10X,4I16/(16X,5G16.8))
          END
```

```
0001            SUBROUTINE COMP4
          C        COMPUTES EQUIPMENT MISSIONS ACCOMP, REL, AVAIL.
          C       COMPUTE COMPONENT   MISSIONS ACCOMP, REL, AVAIL.
          C          STEP SYSTEMS - RESULTS
0002            IMPLICIT REAL * 4 (A-H,O-Z)
0003            COMMON T,TAU,XMAR
0004            COMMON CURVEX(400),CURVEY(400),PCINAM(10,400),CURNAM(10,100)
0005            COMMON WEIBA(400),WEIBB(400)
0006            COMMON PROD(3),TOT(6)
0007            COMMON XNK,XXK,XXKP
0008            COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
0009            COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
0010            COMMON AC,AV,RE
0011            COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100 ),P(100 ,2)
0012            COMMON RKLO,SSLIFE,EPS,GAMMA2
0013            COMMON ITLE(20),NMISS,IOPT1,NTYPES,IPR,   NLIST,MLIST(500),MSTART
0014            COMMON MISNAM(10),MISDES(20,5)
0015            COMMON I,IM1,ITYPES
0016            COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
0017            COMMON IBEG(100),IENAME(4),ICNAME(4)
0018            COMMON NFAILS,IVEND1(10),IVEND2(10),MODTYP(10)
0019            COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
0020            COMMON IKFRB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
0021            COMMON IREAD,IWRITE,IFUNAM(4)
0022            AC  = OMEGA(2)
0023            AV  = OMEGA(1)
0024            IF (AV .NE. 0.)  GO TO 21
0025            RE =0.
0026            GO TO 22
0027         21 CONTINUE
0028            RE = AC / AV
0029         22 CONTINUE
0030            TOT(1) = TOT(1) + AC
0031            TOT(2) = TOT(2) + AV
0032            TOT(3) = TOT(3) + RE
0033            IF (XNK .NE. 1. .OR. XXK .NE. 1. .OR. XXKP .NE. 1.)  GO TO 5
0034            SUMBAC = AC
0035            SUMBAV = AV
0036            SUMBRE = RE
0037            GO TO 6
0038          5 CONTINUE
0039            CALL SUMB1
0040          6 CONTINUE
0041            TOT(4) = TOT(4) + SUMBAC
0042            TOT(5) = TOT(5) + SUMBAV
0043            TOT(6) = TOT(6) + SUMBRE
0044            READ (IREAD)  IIN,PROD
0045            PROD(1  ) = PROD(1  ) * SUMBAC
0046            PROD(2  ) = PROD(2  ) * SUMBAV
0047            PROD(3  ) = PROD(3  ) * SUMBRE
0048            WRITE (IWRITE)  IIN,PROD
0049            IF (IPR.NE.0) WRITE(16,401) I,  AC,AV,RE,XNK,   (TOT(M1),M1=1,6),
               1                   SUMBAC,SUMBAV,SUMBRE,(PROD(M1  ),M1=1,3)
0050            IF (ITYPES .NE. 1)  GO TO 3
0051            IF (NLIST .GE. 500)  RETURN
0052            IF (I .EQ. 1)  GO TO 11
```

```
      IF (I .LE. JMAX1 .AND. I-I(/JDEL1)*JDEL1 .EQ. 0)  GO TO 11
      IF II .GE. JMAX1 .AND. (-((/JDEL2)*JDEL2 .EC. 0)  GO TO 11
      RETURN
   11 CONTINUE
      NLIST = NLIST + 1
      MLIST(NLIST) = 1
      GO TO 12
    3 CONTINUE
      IF (MSTART .GT. NLIST)  RETURN
      DO 13   M=MSTART,NLIST
      IF (I - MLIST(M))  14,12,13
   13 CONTINUE
      MSTART = NLISI + 1
      RETURN
   14 MSTART = M
      RETURN
   12 CONTINUE
      XNUP1 = 1
      SUMT = RHOT*XNUP1
      TE11 = TOT(1) / XNUP1
      TE12 = TOT(2) / XNUP1
      TE13 = TOT(3) / XNUP1
      WRITE (18,101) I,SUMT,   AC,AV,RE,   TE11,TE12,TE13
      TE14 = TOT(4) / XNUP1
      TE15 = TOT(5) / XNUP1
      TE16 = TOT(6) / XNUP1
      WRITE (19,101) I,SUMT,   SUMBAC,SUMBAV,SUMBRE,TE14,TE15,TE16
      RETURN
  101 FORMAT (I10,F10.1,3F10.6,5X,3F10.6,2F10.6)
  401 FORMAT (6H COMP4,2X,I5,5X,5G16.8/(16X,5G16.8))
      END
```

```
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0001            SUBROUTINE PRTOT
0002            IMPLICIT REAL * 4 (A-H,O-Z)
0003            COMMON T,TAU,XMAR
0004            COMMON CURVEX(400),CURVEY(400),PUNAM(10,400),CURNAM(10,100)
0005            COMMON WEIBA(400),WEIPB(400)
0006            COMMON PROD(3),TOT(5)
0007            COMMON XNK,XXK,XXKP
0008            COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
0009            COMMON SUMBAC,SUMBAV,SUMBRF,OMEGA(2)
0010            COMMON AC,AV,RL
0011            COMMON RHOT,RXL(100 ),BETA(100 ),GAMMA(100 ),P(100 ,2)
0012            COMMON RXLO,SSLIFE,EPS,GAMMA2
0013            COMMON ITLE(20),NMISS,IOPT1,NTYPES,IPR,    NLIST,MLIST(500),MSTART
0014            COMMON MISNAM(10),MISDES(20,5)
0015            COMMON I,IM1,ITYPES
0016            COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
0017            COMMON IBEG(100),IENAME(4),ICNAME(4)
0018            COMMON NFAILS,IVEN01(10),IVEN02(10),MODTYP(10)
0019            COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
0020            COMMON IRFRB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
0021            COMMON IREAD,IWRITE,IFUNAM(4)
0022            REWIND  IREAD
0023            M = 1
0024            DO 1 J=1,3
0025          1 TOT(J) = 0.
0026            WRITE (19,971)  (ITLE(K),K=1,19)
0027            WRITE (19,972)
0028            DO 2 I=1,NMISS
0029            READ (IREAD)   IIN,PROD
0030            DO 3 J=1,3
0031          3 TOT(J) = TOT(J) + PROD(J  )
0032            IF (I-MLIST(M))  2,4,6
0033          4 XNUP1 = I
0034            SUMT =     T*XNUP1
0035            TE4 = TOT(1) / XNUP1
0036            TE5 = TOT(2) / XNUP1
0037            TE6 = TOT(3) / XNUP1
0038            WRITE (19,101) I,SUMT,    (PROD(J  ),J=1,3),TE4,TE5,TE6
0039            M = M + 1
0040            IF (M - NLIST)  2,2,6
0041          2 CONTINUE
0042          6 CONTINUE
0043            RETURN
0044        101 FORMAT (I10,F10.1,3F10.6,5X,3F10.6,2F10.6)
0045        971 FORMAT (1H1,20X,19A4//
               *  45X,25HSYSTEM RESULTS VERSUS AGE)
0046        972 FORMAT (10HO  MISSION,10H    USAGE ,11(1H*),9H MISSION ,10(1H*),
               *   5X,11(1H*),9H AVERAGE ,10(1H*)/  2X,
               *   10H  NUMBER  ,10X,10HACCOMPLSH ,10HREADINESS ,10HRELIABLTY ,5X,
               *   10HACCOMPLSH ,10HREADINESS , 9HRELIABLTY/)
0047            END
```

```
0001          FUNCTION COMPRK(TE1,IBFAIL,IEFAIL)
        C          COMPUTE RK
0002          IMPLICIT REAL * 4 (A-H,O-Z)
0003          COMMON T,TAU,XMAP
0004          COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
0005          COMMON WEIBA(400),WEIBB(400)
0006          COMMON PROD(3),TOT(6)
0007          COMMON XNK,XXK,XXKP
0008          COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
0009          COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
0010          COMMON AC,AV,RE
0011          COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100 ),P(100 ,2)
0012          COMMON RKLO,SSLIFE,EPS,GAMMA2
0013          COMMON ITLE(20),NMISS,IOPT1,NTYPES,IPR,    NLIST,MLIST(500),MSTART
0014          COMMON MISNAM(10),MISDES(20,5)
0015          COMMON I,IM1,ITYPES
0016          COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
0017          COMMON IBEG(100),IENAME(4),ICNAME(4)
0018          COMMON NFAILS,IVEN01(10),IVEN02(10),MODTYP(10)
0019          COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
0020          COMMON IREFB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
0021          COMMON IREAD,IWRITE,IFUNAM(4)
0022          REAL * 8 TE1DUB,S8,F8,EPS8
0023          DIMENSION AUX(30)
0024          TE2 = 1.
0025          DO 2  IFAILS=IBFAIL,IEFAIL
0026          IF (MODTYP(IFAILS) .EQ. 2)  GO TO 3
0027          TE3 = CURVE(IVEN01(IFAILS),TE1,0)
0028          GO TO 7
0029        3 CONTINUE
        C                  DO GAUSSIAN QUADRATURE
0030          I1 = IVEN01(IFAILS)
0031          I2 = IVEN02(IFAILS)
0032          TE1DUB = TE1
0033          EPS8 = EPS
0034          J = 2
0035       12 CONTINUE
0036          CALL AUGAUS(0.D0,TE1DUB, EPS8,S8,J,F8,1.D-5 )
0037          IF (J-1)  99,11,13
0038       11 CONTINUE
0039          X = F8
0040          F1T = CURVE(-I1   , X,0)
0041          R2T = CURVE(I2,TE1-X,0)
0042          F8 = F1T * R2T
0043          GO TO 12
0044       13 CONTINUE
0045          RITE1 = CURVE(I1,TE1,    0)
0046          TE3 = RITE1 + S8
0047        7 CONTINUE
0048          TE2 = TE2 * TE3
0049        2 CONTINUE
0050          COMPRK = TE2
0051          RETURN
0052       99 WRITE (6,301) TE1
0053          STOP
0054      301 FORMAT (26H0COMPRK CANNOT EVALUATE RK,E16.8)
0055          END
```

```
0001          SUBROUTINE AUGAUS(A,B,R,S,J,F,RP)
        C                          360-135
0002          DIMENSION XOATX(14),XCATW(14)
0003          REAL * 8 IT,LR,NR,A,B,R,S,E,F,X1,X2,X2PX1,X2MX1,Q6,Q8,XOATX
0004          REAL * 8 XDATW,RP
0005          DATA XOATX/-0.932469514203152,-C.661209386466265,
             1   -0.238619186081397,+0.238619186083197,
             2   0.661209386466265,+0.932469514203152,
             3   -0.960289856497536,-0.796666477413627,
             4   -0.525532409916329,-0.183434642495650,
             5   +0.183434642495650,+0.525532409916329,
             6   +0.796666477413627,+0.960289856497536/
0006          DATA XDATW/+0.171324492379170,+0.360761573048139,
             1   +0.467913934572691,+0.467913934572691,
             2   +0.360761573048139,+0.171324492379170,
             3   +0.101228536290376,+0.222381034453374,
             4   +0.313706645877887,+0.362683783378362,
             5   +0.362683783378362,+0.313706645877887,
             6   +0.222381034453374,+0.101228536290376/
0007          IF (J - 1)  3,4,1
0008        1 IF (J - 2)  3,2,2
0009        3 J = 0
0010          RETURN
0011        2 S =0.D0
0012          IT = 34359738368.D0
0013          J = 1
0014          LR = IT
0015          NR = IT
0016       11 N = 1
0017          X1 = A+(((IT-LR)*(B-A))/IT
0018          X2 = X1+NR*(B-A)/IT
0019          X2PX1 = X2 + X1
0020          X2MX1 = X2 - X1
0021          Q6 = 0.0D0
0022          Q8 = 0.0D0
0023          F = (X2MX1*XOATX(N)+X2PX1)*.5D0
0024          RETURN
0025        4 F = F+0.1D-74
0026          IF (N - 6)  5,5,6
0027        5 Q6 = Q6+F*XDATW(N)
0028          N = N + 1
0029          F = (X2MX1*XDATX(N)+X2PX1)*.5D0
0030          RETURN
0031        6 Q8 = Q8+F*XDATW(N)
0032          N = N + 1
0033          IF (N - 14)  7,7,8
0034        7 F = (X2MX1*XDATX(N)+X2PX1)*.5D0
0035          RETURN
0036        3 CONTINUE
0037          IF (DABS(Q8) .LT. RP)  GO TO 9
0038          IF (DABS(Q6-Q8)-R*DABS(Q8))  9,9,10
0039       10 NR = NR * .5D0
0040          IF (NR - 1.0D0)  11,3,11
0041        9 LR = LR - NR
0042          S = S+Q8*(X2-X1)*.5D0
0043          IF (LR)  13,12,13
```


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```
   12 J = 2
      RETURN
   13 IF (DABS(QQ) .LT. RP)  GO TO 14
      IF (DABS(Q6-Q8)-R*DABS(Q8)*.125D0)  14,14,111
   14 NR = NR*2.D0
  111 IF (LR - NR)  110,11,11
  110 NR = LR
      GO TO 11
      END
```

```
      FUNCTION CURVE(IX,X,IWEIBU)
C        LOOK UP CURVES WITH VALUES BETWEEN 0 AND 1
      IMPLICIT REAL * 4 (A-H,O-Z)
      COMMON T,TAU,XMAR
      COMMON CURVEX(400),CURVEY(400),PGINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON PROD(3),TOT(6)
      COMMON XNK,AKK,XKK2
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELIT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
      COMMON AC,AV,RE
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100 ),P(100 ,2)
      COMMON RKLO,SSLITE,EPS,GAMMA2
      COMMON ITLE(20),NMISS,IOPT(,NTYPES,IPR,   NLIST,MLIST(500),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IMI,ITYPES
      COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),ICNAME(4)
      COMMON NFAILS,IVEN01(10),IVEN02(10),MODTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IRFRB,ICYC,ICYCMI,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      CURVE = O.
      IC = IX
      ISWTCH = 0
      IF (IC)  31,2,1
C          CURVE NUMBER NEGATIVE IMPLIES COMPUTE NEGATIVE DERIVATIVE
   31 CONTINUE
      ICABS = -IC
      IF (NCOPT(ICABS))  32,32,33
   32 IC = ICABS + 1
      GO TO 3
   33 IF (NCOPT(ICABS - 1)  34,34,98
   34 ISWTCH = 1
      IC = ICABS
      GO TO 4
    1 CONTINUE
      IF (NCOPT(IC))  3,3,4
    3 CONTINUE
      ISTORE = IBEG(IC)
      CURVE = YLIN36(NSIZE(IC),CURVEX(ISTORE),CURVEY(ISTORE),X)
    5 IF (CURVE .LT. O.    .OR. CURVE .GT. 1.  )  GO TO 99
    2 RETURN
    4 CONTINUE
      I2 = NSIZE(IC)
      SUM4 = O.
      SUM5 = O.
      PROD4 = 1.
      ISTORE = IBEG(IC)
      DO 11 I3=1,I2
      TEIO = WEIBA(ISTORE)*X**WEIBB(ISTORE)
      IF(IWEIBU .EQ. O)  GO TO 21
      IF (TEIO .GT. 100.)  GO TO 11
      PROD4 = PROD4*(1.-EXP(-TEIO))
      GO TO 11
   21 CONTINUE
```


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```
      SUM4 = SUM4 + TE10
      IF (ISWITCH .EQ. 0)  GO TO 11
      SUM5=SUM5+WEIBA(ISTORE)*WEIBB(ISTORE)*X**(WEIBB(ISTORE)-1.)
   11 CONTINUE
      IF (IWEIBU .EQ. 0)  GO TO 22
      CURVE = PROD4
      GO TO 5
   22 CONTINUE
      IF (SUM4 .GT. 100.   )  GO TO 12
      CURVE =  EXP(-SUM4)
      IF (ISWITCH .EQ. 1)  CURVE=CURVE*SUM5
      GO TO 5
   12 CURVE = 0.
      RETURN
   99 WRITE (6,301) IX,X,CURVE,L,I
      STOP
   98 WRITE (6,302) IX,X,IXC2,NCOPT(ICABS)
      STOP
  301 FORMAT (19HOCURVE OUT OF RANGE,I5,G16.8,2I5)
  302 FORMAT (28HONCOPT NOT 0 OR 1 IN RK COMP,I10,E16.8,2I10)
      END
```

FORTRAN IV G LEVEL 21 COMPAB DATE = 76257 18/06/37 PAGE 0001

```
      SUBROUTINE COMPAB(XMU,P,A,B,NACC)
      IMPLICIT REAL *4 (A-H,O-Z)
      NTIMES = 0
      PTEST =  EXP(-1.  )
      BT=2.
      IF (P .LT. PTEST)  BT=(.5  /PTEST)*P
      NACCT=NACC
      TE1 = -ALOG(P)
      CALL WEG(1,BT,NACCT,N)
    2 CONTINUE
      IF (NTIMES .GT.  30) GO TO 8
      TE5 = 1.  /BT
      BT = .5* GAMMA(TE5)*TE1**(-TE5)
      NTIMES = NTIMES + 1
      CALL WEG(2,BT,0,N)
      IF(N)  1,2,1
    1 B=BT
      TE4= GAMMA(1.  /BT+1.  )
      A=(XMU/TE4)**(-BT)
      RETURN
    8 WRITE (6,103) XMU,P,NACC,NTIMES
      GO TO 1
  103 FORMAT (24H0TROUBLE SOLVING FOR A,B,2G16.8,I5,I5)
      END
```

```
FORTRAN IV G LEVEL  21              WEG              DATE = 76257        18/06/37            PAGE 0001

 0001               SUBROUTINE WEG1(I,XNP1,J,N)
              C     360 VERSION OF WEG 360-35
 0002               IMPLICIT REAL * 4 (A-H,O-Z)
 0003               GO TO (1,2),I
 0004             1 K = 1
 0005               XBN = XNP1
 0006               XTEMP=10.  **(-J)
 0007               XP = XNP1
 0008               RETURN
 0009             2 GO TO (3,4),K
 0010             3 IF( ABS(XP-XNP1)-XTEMP* ABS(XP)) 5,5,8
 0011             8 XP=XNP1
 0012               XBNM1 = XBN
 0013               XBN = XNP1
 0014               K = 2
 0015             7 XN = XNP1
 0016               XNP1 = XBN
 0017               N = 0
 0018               RETURN
 0019             4 XBNP1 =    ((XNP1*XBNM1)-(XN*XBN))/(XNP1+XBNM1-XN-XBN)
 0020               IF(( ABS (XP-XBNP1))-( ABS (XTEMP*XP)))5,5,6
 0021             6 XP = XBNP1
 0022               XBNM1 = XBN
 0023               XBN = XBNP1
 0024               GO TO 7
 0025             5 N = 1
 0026               RETURN
 0027               END
```

```
      FUNCTION YLIN36(N,XL,YL,X)
      IMPLICIT REAL * 4 (A-H,O-Z)
      DIMENSION XL(10),YL(10)
      IF (N - 1) 5,5,6
    6 DO 1 I=1,N
      IF (X - XL(I)) 3,2,1
    1 CONTINUE
      I = N
      GO TO 4
    3 IF (I.EQ.1) I=2
    4 YLIN36 = YL(I-1) + ((X-XL(I-1))/(XL(I)-XL(I-1))) * (YL(I)-YL(I-1))
      RETURN
    2 YLIN36 = YL(I)
      RETURN
    5 YLIN36 = YL(1)
      RETURN
      END
```

```
      SUBROUTINE SUMB1
C         COMPUTATION OF EQUIPMENT AVAILABILITY AND ACCOMPLISHMENT
      IMPLICIT REAL * 4 (A-H,O-Z)
      COMMON T,TAU,XMAR
      COMMON CURVEX(400),CURVEY(400),PCINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON PROD(3),TOT(6)
      COMMON XNK,XXK,XXKP
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
      COMMON AC,AV,RE
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100 ),P(100 ,2)
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON ITLE(20),NMISS,IOPT1,NTYPES,IPR,   NLIST,MLIST(500),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),ICNAME(4)
      COMMON NFAILS,IVENO1(10),IVENO2(10),MODTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IRERB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      IF (AV .EQ. 0.)  GO TO 7
      QAV = 1.-AV
      XKC = XNK
      TERM = AV**XNK
      XMULT = QAV/AV
      SUMBAV = TERM
      CALL SUMB(XKC,XXKP,RE,SUM3)
      SUMBAC = TERM*SUM3
      IF (XKC .EQ. XXK)  GO TO 10
    5 CONTINUE
    4 XKCN = XKC-1.
      TE3 = (XKC/(XNK-XKCN))*XMULT
      TERM = TERM * TE3
      SUMBAV=SUMBAV+TERM
      XKC = XKCN
      CALL SUMB(XKC,XXKP,RE,SUM3)
      SUMBAC=SUMBAC+TERM*SUM3
      IF (XKC .GT. XXK)  GO TO 5
   10 CONTINUE
      IF (SUMBAV .EQ. 0.)  GO TO 11
      SUMBRE = SUMBAC / SUMBAV
      RETURN
    7 SUMBAC = 0.
      SUMBAV = 0.
   11 CONTINUE
      SUMBRE = 0.
      RETURN
      END
```

```
      FUNCTION YLIN36(N,XL,YL,X)
      IMPLICIT REAL * 4 (A-H,O-Z)
      DIMENSION XL(10),YL(10)
      IF (N - 1) 5,5,6
    6 DO 1 I=1,N
      IF (X - XL(I)) 3,2,1
    1 CONTINUE
      I = N
      GO TO 4
    3 IF (I.EQ.1) I=2
    4 YLIN36 = YL(I-1) + ((X-XL(I-1))/(XL(I)-XL(I-1))) * (YL(I)-YL(I-1))
      RETURN
    2 YLIN36 = YL(I)
      RETURN
    5 YLIN36 = YL(1)
      RETURN
      END
```

```
FORTRAN IV G LEVEL  21              SUMBIN             DATE = 76257          18/06/37             PAGE 0001

 0001              SUBROUTINE SUMBIN(XM,XK,P,SUM)
             COMPUTES SUM OF BINOMIAL WITH PROB P FROM XK TO LIMIT XM FOR XM TRIALS
 0002              IMPLICIT REAL * 4 (A-H,O-Z)
 0003            2 IF (P)  7,7,8
 0004            8 Q = 1.-P
 0005              XKC = XM
 0006              TERM = P**XM
 0007              XMULT = Q/P
 0008              SUM1 = TERM
 0009            5 IF(XKC-XK)  6,6,4
 0010            4 XKCN=XKC-1.
 0011              TE3 = (XKC/(XM-XKCN)) * XMULT
 0012              TERM = TERM*TE3
 0013              SUM1=SUM1+TERM
 0014              XKC=XKCN
 0015              GO TO 5
 0016            6 SUM=SUM1
 0017              RETURN
 0018            7 SUM=0.
 0019              RETURN
 0020              END
```

JOB DECK LISTING
WITH TEST DATA

```
//GO.FT05F001 DD *
  RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE
   25  100     5     .0001                          BOOT STRAP 1
CONSU FLIGHT




    1    25     1     1
          3
ANNA                                2         2         1
LITTLE ANNA                   1     1    1    2    3    4   .98    26 HOURS
2  5  6
BARBARA                             1         1         1
BARBARA                       2     1    7    8    9   10  1.0    15 HOURS
2 11 121 13
CHLOE                              10         9         7
CHLOE                         1   .75   14   15   16   17  .95    25  HOURS
1 18
//GO.FT09F001 DD *
         18
          1           1          4           CURVE 1     LITTLE ANNA
                      1        .95           ALPHA       LITTLE ANNA
          1           1          4           CURVE 2     LITTLE ANNA
                   1000        .98           BETA        LITTLE ANNA
          1           1          4           CURVE 3     LITTLE ANNA
                   1000        .98           GAMMA1      LITTLE ANNA
          1           1          4           CURVE 4     LITTLE ANNA
                      1     .60656           GAMMA2      LITTLE ANNA
          1           2          4           CURVE 5     LITTLE ANNA
             .00000029        2.78           STAGE 1     LITTLE ANNA
          1           1          4           CURVE 6    LITTLE ANNA
                    100        .95           STAGE2     LITTLE ANNA
          1           1          4           CURVE 7    BARBARA
                      2        .90           ALPHA      BARBARA
          1           1          4           CURVE 8    BARBARA
                      1        .90           BETA       BARBARA
          1           1          4           CURVE 9    BARBARA
                    100        .90           GAMMA1     BARBARA
          1           1          4           CURVE 10   BARBARA
                      4        .95           GAMMA2     BARBARA
          1           1          4           CURVE 11   BARBARA
                    100         .9           STAGE 1    BARBARA
          1           1          4           CURVE 12   BARBARA
                     50     .60656           STAGE 2    BARBARA
          1           1          4           CURVE 13   BARBARA
                    200        .99           STAGE 1    BARBARA
          1           1          4           CURVE 14    CHLOE
                      1     .60656           ALPHA       CHLOE
          1           1          4           CURVE 15    CHLOE
                    400        .98           BETA        CHLOE
          1           1          4           CURVE 16    CHLOE
                    400        .98           GAMMA 1     CHLOE
          1           1          4           CURVE 17    CHLOE
                      2     .60656           GAMMA 2     CHLOE
          1           1          4           CURVE 18    CHLOE
                    180       .995           IFVNO1      CHLOE
//GO.FT06F001  DD  SYSOUT=A,DCB=(RECFM=FA.LRECL=133.BLKSIZE=133)
//GO.FT16F001  DD  SYSOUT=A.DCB=(RECFM=FA.LRECL=133,BLKSIZE=133)
//GO.FT17F001  DD  SYSOUT=A.DCB=(RECFM=FA.LRECL=133.BLKSIZE=133)
//GO.FT18F001  DD  SYSOUT=A.DCB=(RECFM=FA,LRECL=133.BLKSIZE=133)
//GO.FT19F001  DD  SYSOUT=A.DCB=(RECFM=FA,LRECL=133.BLKSIZE=133)
//GO.FT20F001  DD  SYSOUT=A.DCB=(RECFM=FA.LRECL=133.BLKSIZE=133)
```

```
//GO.FT21F001 DD UNIT=SYSDA,DISP=(NEW,PASS),DSN=&&FT21,
//   DCB=(RECFM=VBS,LRECL=20,BLKSIZE=2000),SPACE=(CYL,(1,1))
//GO.FT22F001 DD UNIT=SYSDA,DISP=(NEW,PASS),DSN=&&FT22,
//   DCB=(RECFM=VBS,LRECL=20,BLKSIZE=2000),SPACE=(CYL,(1,1))
/*
/*
/*EOF
```

APPENDIX C.2

PART 2

Appendix C.2

Part 2

EQUIPMENT-MISSION COST-SPARES MODEL

Version 4

Fred S. Zusman

Original Date
June 8, 1976

INTRODUCTION

This Fortran computer program is an implementation of the fourth version of a model developed by W.H. Cook of COBRO to compute equipment-mission reliability and availability. A mathematical description of the model is provided in Appendix C.1. This version allows for two-step failures and a breakout of mission failure results by cause.

SUMMARY

This program reads data describing the failure rates, repair parameters, and usage characteristics of the components in a complete system. The output of the program is (1) a summary for each equipment of its expected maintenance actions and their cost by type (and for mission failures, by mode); (2) a table of component spares usage probabilities for the system-equipment configuration; (3) a summary for the total system of support costs by type; and (4) a summary of system costs by criticality of failure mode. The prints are given for specified numbers of missions. The details of the computation are given in the above mentioned paper. The program and its usage are described herein.

INPUT

After reading a set of curve inputs, the program reads groups of the input cards described in detail below and computes the values of the output parameters. After printing the results for each component and a system of component, another group of input cards is read. The program stops if no more sets of data are to be read or if there are any data errors. Each set consists of control inputs and component-equipment inputs.

CURVE INPUT DATA BASE (CARDS OR DISK) (Unit 9) (CURVIN)

Card	Columns	Description*
1	1-10	NCURVE, number of curves to be read from the curve data base (1-100)
		For each curve, the following cards (2-3) are needed:
2	1-10	NSIZE, number of points in this linear curve or number of phases in this Weibull curve (usually 1)
	11-20	NCOPT, this curve option code:
		0 linear segment curve for which (X,Y) segment end points follow
		1 Weibull curve for which μ's and $P(\mu/2)$'s follow for each failure phase
		2 Weibull curve for which A's and B's follow for each failure stage
	21-30	NACC, figures of accuracy for computation of A and B in Weibull (usually 4) if the μ's and $P(\mu/2)$'s are given as input
	41-80	CURNAM, 40 character curve name for descriptive purposes
3.0		For each end point of a linear segment curve, the following card is needed (NCOPT = 0)
	1-10	Identification (NOT USED) (for sequencing deck-safety feature)
	11-20	CURVEX, independent variable of first point
	21-30	CURVEY, dependent variable of first point
	41-80	POINAM, 40 character point I.D.--Printed on output Card 3.0 is repeated for each point with the points in order by increasing CURVEX.
OR 3.1		Weibull parameter card for first failure phase (NCOPT = 1 or 2)
	1-10	Identification (NOT USED)
	11-20	μ or A of Weibull distribution for first failure phase
	21-30	$P(\mu/2)$ or B of Weibull distribution for first failure phase $(P \geqq .15)$
	41-80	POINAM, 40 character distribution I.D. if desired. Card 3.1 is repeated for each phase.

*Integer fields are right justified.

Cards 2 and 3 are repeated for each linear segment or Weibull curve. The linear curves are currently looked up as a linear interpolation for data within the set of points and a linear extrapolation for data outside the point set. One-point curves are considered to be constants.

Where the derivative of a linear curve is required in the computation, the program assumes that its derivative follows in this Curve Data Base.

CONTROL INPUT CARDS (Unit 5) (INPUT1)

Card	Column	Description
1	1-76	ITLE, any 76 character title for run
	77-80	IPR, debug print option code 0 ⇒ no debug print 1 ⇒ give debug print
2	1-5	NMISS, number of missions to be run through (1-100)
	6-10	T, length of all missions (in hrs)
	11-15	Tau, interval between missions (in hrs)
	16-25	EPS, accuracy for GAUSSIAN QUADRATURE routine (usually .00001)
	41-80	MISNAM, 40 character mission name
3-7	1-80	MISDES, 5 card mission description; 5 cards required, may be blank
8	1-5	JDEL1, step for mission printout up until mission JMAX1 *
	6-10	JMAX1, limit for use of JDEL1
	11-15	JDEL2, step for mission printout after JMAX1
	16-20	ISYS, number of systems which are to be used
	21-25	NCRIT, number of critical failure modes (1-5)

*Note that currently the results for at most 10 missions can be printed and that the results for the last mission are always printed regardless of the values of JDEL1, JMAX1, and JDEL2.

COMPONENT INPUT CARDS (Unit 5) (COMP, RDCOMP)

Card	Column	Description
1	1-10	NTYPES, number of components/equipments
		For each component/equipment, the following cards (2-8) are needed
2	1-16	IENAME, 16 character equipment name
	21-30	XNK, number of components in this equipment
	31-40	XXK, number of components required for readiness of equipment (not used)
	51-60	MSPAR, maximum spare (<200) allowed for this component
	68-80	IFUNAM, functional group and position of the component
3	1-16	ICNAME, 16 character name of component
	21-25	NFAILS, number of mission failure modes for this component (1-10)
	26-30	RHO, usage rate of component or missions
	31-35	IALPHA, curve number for computation of α as function of interval
	36-40	IBETAC, curve number for computation of β (non renewing probability) as function of time used
	41-45	IGAMM1, curve number for computation of γ_1 (probability of initiating renewal) as function of time used
	46-50	IGAMM2, curve number for computation of γ_2, (renewal probability) as function of interval
	51-55	DELTA, δ (probability that handling between missions will not cause a failure)
	56-60	IRFRB, rebuild cycle (missions) (not used)
	61-80	UNIT, 20 character description of usage variable (e.g., hours, miles)
4	1	MODTYP(1), mode type for first failure mode ($1 \Rightarrow$ use curve defined by IEVN01, $2 \Rightarrow$ use two step failure defined by curves IEVN01 and IEVN02).
	2-3	IEVN01(1), curve number to use to compute R_1 as function of time used
	4-5	IEVN02(1), curve number to use to compute R_2 as function of time used
		If R_1, is a linear curve and MODTYP=2, then the next curve in the curve list must be f_1.
	6	ICR(1), criticality of this failure mode for computation of support costs by criticality at the system level.
	7-12	Same data for failure mode 2, if any.
	13-18	Etc. for up to 10 failure modes as needed.

Card	Column	Description
5	1-6	CK(1), cost per man hour-service
	7-12	CK(2), cost per man hour-preventive maintenance
	13-18	CK(3), cost per man hour-handling/transportation failure
	19-24	CK(4), material cost-per service
	25-30	CK(5), material cost-per preventive maintenance
	31-36	CK(6), material cost-per handling/transportation failure
	37-42	CK(7), cost of unavailability
	43-48	CK(8), cost of unreliability
	49-54	HK(1), man hours per service
	55-60	HK(2), man hours per preventive maintenance
	61-66	HK(3), man hours per handling/transportation failure
	67-72	HK(4), man hours per mission failure (not used)
	73-78	HK(5), operating interval per service action
6	1-6	CK3(1), the cost per man hour for corrective maintenance for 1st failure mode.
	7-12	CK3(2), the cost per man hour for corrective maintenance for 2nd failure mode.
	⋮	
	55-60	CK3(10), the cost per man hour for corrective maintenance for 10th failure mode.
7	1-6	CK6(1), the material cost for corrective maintenance for 1st failure mode.
	7-12	CK6(2), the material cost for corrective maintenance for 2nd failure mode.
	⋮	
	55-60	CK6(10), the material cost for corrective maintenance for 10th failure mode.
8	1-6	HK4(1), the man hours per mission failure, for 1st failure mode.
	7-12	HK4(2), the man hours per mission failure, for 2nd failure mode.
	⋮	
	55-60	HK4(10), the man hours per mission failure, for 10th failure mode.

PROGRAM AND SUBPROGRAM DESCRIPTIONS

MAIN - Main Program

This main program calls subroutines to 1) read curve inputs; 2) read the control inputs; 3) read the equipment inputs; 4) compute the detail results; and 5) print the results. It processes all the sets of inputs on unit 5 and then stops.
Subroutines called: CURVIN, INPUT1, INIT, COMP

CURVIN - Read Curve Inputs

This subprogram reads and checks the curve data base deck. The Weibull A's and B's or μ's and $p(\mu/2)$'s are computed and printed.
Subroutines called: COMPAB

INPUT1 - Read Control Inputs

This subprogram reads and checks the control inputs.

INIT - Initialize System Totals

Clear the system totals and set up print mission.

COMP - Control for Computation

This subprogram controls the computation for each equipment. It uses subroutines to read equipment inputs, compute a, A, ΣA, B, component costs and spares and system costs.
Subroutines called: RDCOMP, INIT2, COMP1, COMP2, COMP3, COMP4, COMP5, COMP6, and PRTOT

RDCOMP - Read Component Inputs

This subprogram reads and checks the component data deck.

INIT2 - Initialize Curve Values and Products

This subprogram computes the values of the mode integral, R_k, β, γ and their products needed in the later computations.
Subroutines called: CURVE, COMPRK, COMPIN.

COMP1 - Compute A

This subprogram computes A recursively for all the missions, causes, and failure modes.

COMP2 - Compute ΣA

This subprogram computes ΣA for all causes, missions, and failure mode.

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4 OF 5

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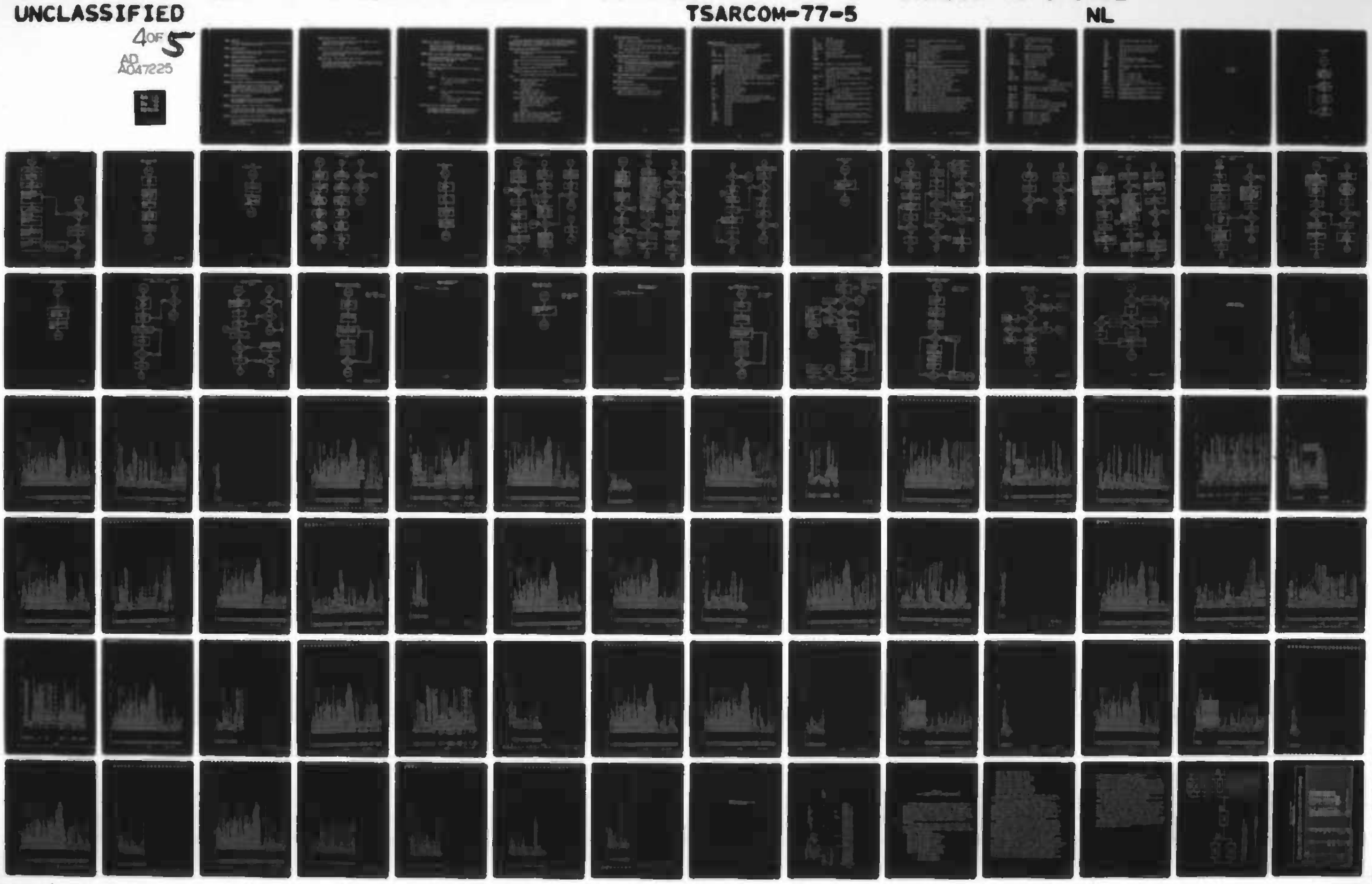
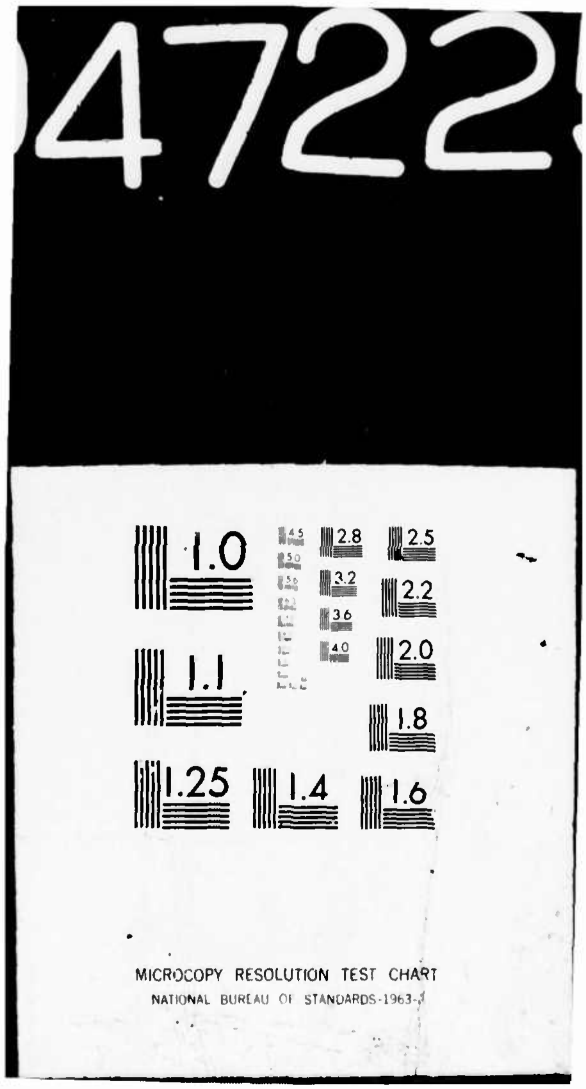



4722
1.0
4.5
5.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

COMP3 - Compute B

This subprogram computes B for all causes and failures for the missions in MLIST. Subroutines called: PMULT1.

COMP4 - Compute Little A's

This subprogram computes the little A's recursively for all the missions, causes, and failure modes.

COMP5 - Compute the Component Results

This subprogram uses the B's to compute the component costs for the numbers of missions in MLIST.

COMP6 - Compute Spares Probabilities

This subprogram uses the B's to compute the spares probabilities for the mission configuration specified by MLIST and ISYS. Subroutines called: PMULT2

PRTOT - Print System Results

Print the system results

PMULT1-(P, A, N, IRP1) - Multiply Two Polynomial with No Constant

This subprogram multiplies the polynomials in P and A together to generate their product in P. N is the degree. The polynomials have no constant terms and the product is limited to degree N. IRP1 is the first non zero term in the answer. (IRP1-1 is the first non zero term in the input P).

PMULT2 - Multiply Two Polynomials

This subprogram multiplies POLY1 and POLY2 to generate POLY3. POLY1 has degree NPOLY1; POLY2 has degree NPOLY2; POLY3 has degree MIN(MSPAR + 1, NPOLY1 + NPOLY2 - 1).

COMPRK (TE1, IBFAIL, IEFAIL) - Compute Survival Probability

This function type subprogram computes the probability of survival (R_k for one or more failure modes. TE1=usage and IBFAIL=first failure mode interest and IEFAIL=the last. Subroutine called: CURVE, AUGAUS

AUGAUS (A, B, R, S, J, F, RP) - Gaussian Quadrature

This is a standard Gaussian Quadrature routine used in this program to compute the two stage integral possibly required for the computation of R_k).
Subroutine called: None

COMPIN (BIN, BFI, IB) - Compute Mode Integral

This function type subprogram computes the mode integral in the "a" computation from BIN to BFI for mode IB.
Subroutine called: AUGUSZ

AUGUSZ (A, B, R, S, J, F, RP) - Gaussian Quadrature

This is another Gaussian Quadrature routine required for the computation of the mode integrals which in the case of two-stage failures involve computing a double integral.

COMPGK (TEl, IH) - Compute the Mode Integral Integral

This function type subprogram computes the value at TEl of the integral for the mode integral for mode IH. It is similar to COMPRK except that the derivative of the IHth mode is used.
Subroutines called: CURVE, AUGAUS

CURVE (IX, X, IWEIBO) - Curve Look-up

This function type subprogram computes the value of the IXth curve using X as the argument. Only answers between 0 and 1 are allowed and the answer may be complemented depending on IWEIBO. Subroutine called: YLIN36

COMPAB (XMU, P, A, B, NACC) - Weibull Parameter Computation

This subprogram computes the A and B of the Weibull distribution using XMU and P with accuracy NACC (figure). Subroutine called: WEG, GAMMA

WEG (I, XNP1, J, N) - Solve X = f(X)

This subprogram permits the iterative solution of an equation of form X = f(X).

Usage:

1st Call: I = 1

XNP1 = initial value on input/new value on output

J = accuracy desired (figures)

N = not used.

Successive Calls: I = 2

XNP1 = f (XNP1) from last call on input/new XNP1 on output

J = not used

N = 0 solution not found so recompute f (XNP1)

N = 1 solution is XNP1.

YLIN36 (N, XL, YL, X) - Linear Curve Look-up

This function type subprogram generates the value, using X as the argument, of the function YL = f(XL) where f (XL) is a linear segment curve specified by the N points (XL, YL).

PRINT OUTPUT

The program generates printed outputs of the inputs as read, as well as optional de-bug information and summary results. The following discussion is broken down by output unit. A Job Deck Listing with test data can be found at the end of this section along with an example of the program output.

UNIT 6--Input and Error Message Print

CURVIN--The curve inputs are printed as read except that for the Weibull distributions.

The A's, B's, μ's and P(μ/2)'s are all printed.

INPUT1--The title and mission data inputs are printed as read.

COMP-- The title is printed as well as the NTYPES input card

If IPR $\neq$ 0 the A's, ASUM's and B's are listed.

RDCOMP--The equipment inputs are printed as read

All error messages are printed as follows and the program usually stops.

CURVIN--NCURVE TOO BIG (NCURVE, LIMIT)
NCOPT OUT OF RANGE
NO ROOM FOR CURVES (LIMIT)
NO CURVE DATA
P TOO SMALL (P, LIMIT)

INPUT1--NMISS TOO BIG (NMISS, LIMIT)
NLIST TOO BIG (NLIST, LIMIT)

RDCOMP--IBETAC OR IGAMM1 OR IGAMM2 OR IALPHA TOO BIG
(IBETAC, IGAMM1, IGAMM2, IALPHA, LIMIT)
NFAILS TOO BIG OR SMALL (NFAILS)
BAD DATA FOR FAILS (IFAILS)
XNK BAD
DELTA BAD

INIT2-- GAMMA1 + BETA GREATER THAN ONE (I, GAMMA, BETA)

COMPRK--COMPRK CANNOT EVALUATE RK (ARGUMENT)

CURVE-- NCOPT NOT 0 OR 1 IN RK COMP (IX, X, IXC2, NCOPT)

COMPAB--CANNOT SOLVE FOR A, B (XMU, P, NACC, NTIMES)

UNIT 16--Debug Print (IPR ≠ 0)

INIT2--I, PRODBE(I), ALPHAL(J), ALPHA(J), DELTAL(I)

COMP1--I, IU, TE1-TE5, A(I,5)

COMP1--N,N, (A(N,J), J=1,5), (A4 (N,IFAILS), IFAILS = 1, NFAILS)

COMP1--I, IU, TE1-TE5, TE11-TE14, TE17, TE18, TE20, TE21, TE27, TE30-TE34, SUM1, A(I,5), SUMA

COMP4--N, (LA(N,J), J=1,5) (LA4 (N,IFAILS), IFAILS=1, NFAILS) LA4SUM(N)

UNIT 18--Component Data and Results Print

INPUT1--The mission data are printed

RDCOMP--The equipment and component data are printed broken down by life characteristics and maintenance, frequency characteristics

INIT2-- The component life and support distribution are printed

COMP5-- The component results are printed

COMP6-- Spare probabilities are printed

UNIT 19--Component Failure Mode Results

COMP5-- The component results are printed broken down by failure mode.

UNIT 20--System Results

PRTOT--System results are printed.

UNIT 21--Component Data and Results Print

COMP5--The component criticality results are printed.

PRTOT--The system criticality results are printed.

COMMON REAL VARIABLES

Currently the Common Real Variables are defined as REAL*4.

T	t, the length in hours of the missions
TAU	The time between missions
XMAR	Mission arrival rate
CURVEX (400)	CURVEX contains the abscissas of the linear curves and the A's or μ's for the Weibull distributions
CURVEY (400)	CURVEY contains the ordinates of the linear curves and the B's or P's for the Weibull distributions
POINAM(10,400)	The 40 character names for the 400 points
CURNAM(10,100)	The 40 character names for the 100 curves
WEIBA (400)	The A's for the Weibull distributions
WEIBB (400)	The B'es for the Weibull distributions
XNK	N_k for the current equipment (total components in the equipment)
XXK	X_k for the current equipment (total components needed for availability) (not used)
XXKP	X_k for the current equipment (total components needed for success) (not used)
ALPHA	The α for this equipment
RHO	Equipment usage rate (ρ)
DELTA	δ for this mission
UNIT (5)	20 character description of units for mission length
SUMT	SUMT is the sum of the usage at the end of the I^{th} mission going back J missions (counting the I^{th})
CAPT	Not used
DELTT	Not used
XIT	Not used
SUMBAC	Not used
SUMBAV	Not used
SUMBRE	Not used
OMEGA(2)	Not used
AC	Not used
AV	Not used

RE	Not used
RHOT	Operating time (RHO*T)
RKL (100)	R_k's for the missions
BETA (100)	β's for the missions
XAMMA (100)	γ's for the missions
RKLO	R_k at start 1st mission
SSLIFE	System service life
EPS	Definition of zero for quadrature routine
GAMMA2	γ_2
PRODBE (100)	PRODBE(I) is the $\prod_{i=1}^{I} \beta_i$ for the B's above.
A(100,5)	The computed A's for each mission for the causes plus the total. (A(I,J)) is the probability of no replacement for I missions for the J^{th} cause.
ASUM (100,5)	The partial sums of the A's
HK(5)	The HK's are the input five hourly rates for the cost computation
CK(9)	The CK's are the eight cost factors for the cost computation
SUMCO (14,10)	SUMCO(I,J) is the I^{th} result for the system at the J^{th} mission number in the MLIST
CRES (14,10)	CRES(I,J) is the I^{th} result for the equipment at the J^{th} mission number in the MLIST
CAUSE (4,5)	These are the 16 character names for the four cause plus total
POLY (100)	The coefficients of the generating polynomial of the A's. Only relevant items computed.
PRFIL (5)	PRFIL contains spares results for the four causes plus total
PRFIL2 (5)	PRFIL2 contains summaries for the spares results
POLY1 (201)	The coefficients of the previous polynomial of spares probabilties
POLY2 (201)	The coefficients of the B polynomial being used to multiply POLY1

POLY3 (201)	The coefficients of the polynomial of spares probabilities
B (101,10,5)	B (I,M,J) is the probability (B) of (I-1) total spares being needed to support MLIST (M) missions for each of the four causes plus total.
ALPHAL (100)	The products of the α's
ALPHAC (100)	The products of the $(1-\alpha)$'s
DELTAL (100)	The products of the δ's
CRESHT (3,10)	The cost results for handling/transportation for 10 missions of labor-per-total
SUMCHT (3,10)	The system cost results for handling/transportation for 10 missions for labor-per-total
LA (100,5)	The a's for each of the 100 missions and 4 causes plus total
LA4 (100,10)	The a_4's for each of the 100 missions and 10 failure modes.
LA4SUM (100)	The sums of the a_4's over all failure modes.
RKLINT (100,10)	The 10 mode integrals for each mission.
PRFL4 (10)	The expected equipment usage for failure by mode
HK4 (10)	The man hours per mission failure by mode.
B4 (101,10,10)	The B polynomials for each failure mode.
A4 (100,10)	The A polynomial for each failure mode.
ASUM4 (100,10)	The partial sums of the A's for each failure mode.
CK3 (10)	The cost per man for CM by mode.
CK6 (10)	The material cost for CM by mode.
CRES47 (10,10)	The cost results for 10 missions and failure modes for labor
CRES48 (10,10)	The cost results for 10 missions and failure modes for personnel
CRES49 (10,10)	The cost results for 10 missions and failure modes total
CRCR47 (10,5)	The system cost results for 5 criticalities for labor
CRCR48 (10,5)	The system cost results for 5 criticalities for personnel
CRCR49 (10,5)	The system cost results for 5 criticalities total

COMMON INTEGER VARIABLES

ITLE (20)	20 word (80 character) run title
NMISS	Total number of missions (1-100)
IOPT1	Not used
NTYPES	Number of equipments/components
IPR	Debug print option code 0 ⇒ no 1 ⇒ yes
NLIST	Number of missions to print (1-100)
MLIST (10)	Number of the missions to print
MSTART	Index for search of MLIST
MISNAM (10)	40 character mission name
MISDES (20,5)	5 card mission description
I	Mission number
IM1	I-1
ITYPES	Equipment number
NCURVE	Number of curves (1-100)
NSIZE (100)	Size of each curve (1-10)
NCOPT (100)	Options for each curve 0 ⇒ segment 1 ⇒ Weibull with A's and B's 2 ⇒ Weibull with μ's and P's
NACC (100)	Accuracy for Weibull computation for each curve
IBEG (100)	Starting place in the CURVEX, CURVEY lists for each curve
IENAME (4)	Equipment name
ICNAME (4)	Component name
NFAILS	Number of failure mode (1-10)
IVENO1 (10)	Curve numbers for first phase of 10 failure modes
IVENO2 (10)	Curve numbers for second phase of 10 failure modes
MODTYP (10)	Mode for each failure mode 1 ⇒ one phase 2 ⇒ two phases
IALPHA	Curve number for α computation
IBETAC	Curve number for β computation
IGAMM1	Curve number for γ_1 computation
IGAMM2	Curve number for γ_2 computation
IRFRB	Refurbish cycle number

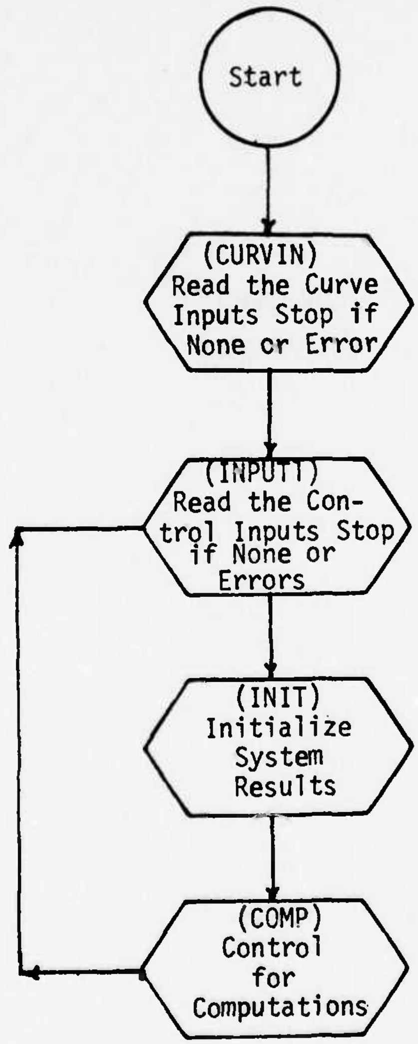
ICYC	Index of mission number in cyclic mode
ICYCM1	ICYC-1
JDEL1	Step for mission print before the JMAX1 mission
JMAX1	Limit for use of previous print mission step
JDEL2	Step for mission print after JMAX1 mission
IREAD	Not used
IWRITE	Not used
IFUNAM (4)	Function group code of equipment
ISYS	ISYS is the number of systems being used
NMISP1	NMISS + 1
MSPAR	Maximum number of spares to compute the probability for (1-200)
MSPAP1	MSPAR + 1
NPOLY1	Degree + 1 of POLY1 (1-201)
NPOLY2	Degree + 1 of POLY2 (1-201)
NPOLY3	Degree + 1 of POLY3 (1-201)
NCRIT	Number of critical failure modes (1-5)
ICR (10)	For the component, the criticality number of each failure mode.
CRPRL4 (5)	The expected corrective maintenance actions results for 10 missions by 5 criticalities.
SUMEX(12,10)	The system results for 10 missions and the expected maintenance actions by types.
SUMEY(6,10)	The system results for 10 missions and the expected corrective maintenance actions by 5 criticalities.

FLOW CHARTS

COST/SPARES

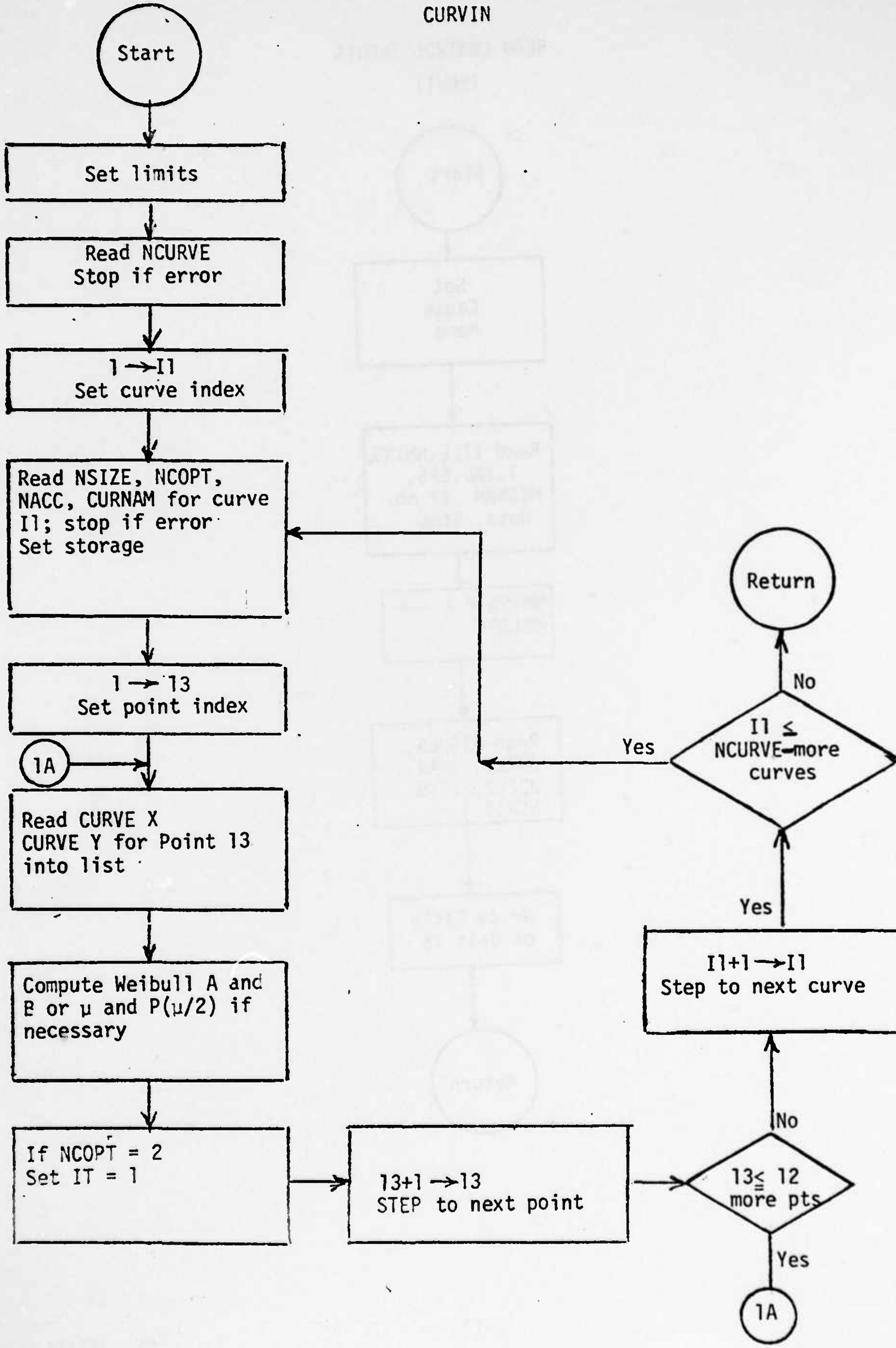
MAIN PROGRAM

MAIN



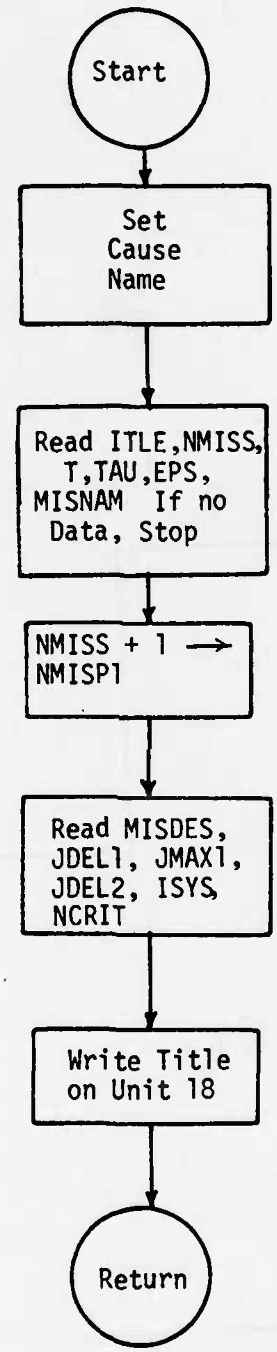
READ CURVE INPUTS

CURVIN



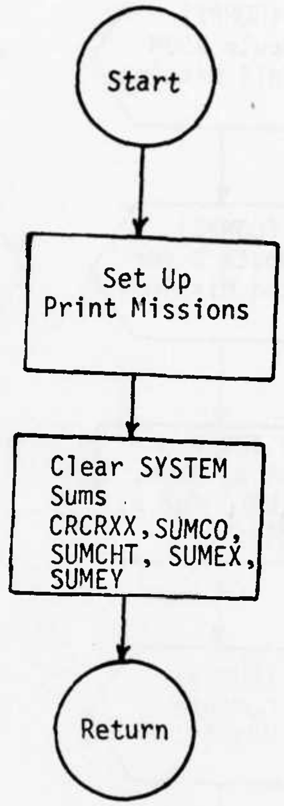
READ CONTROL INPUTS

INPUT1



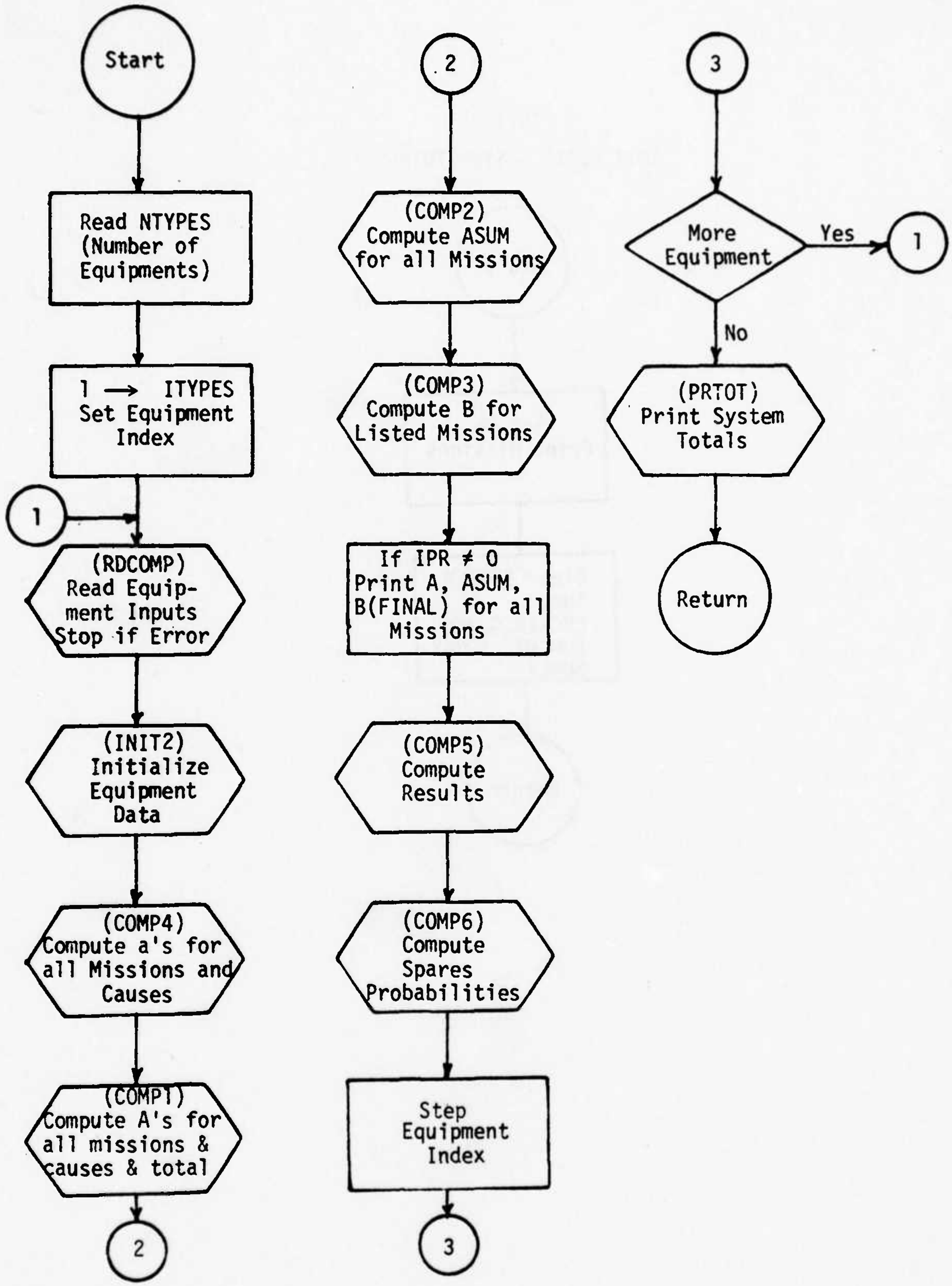
INIT

INITIALIZE SYSTEM TOTALS



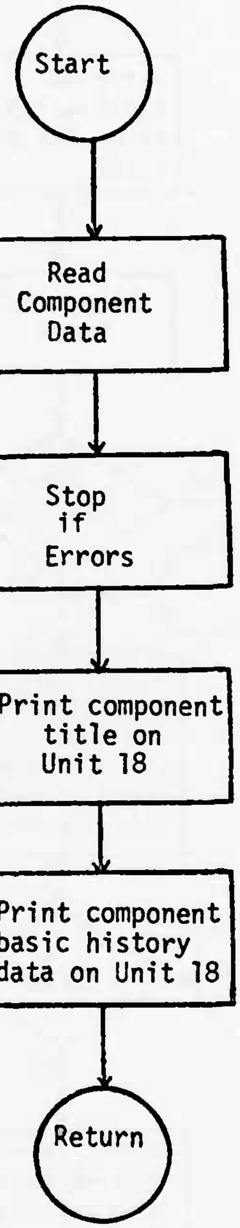
CONTROL FOR COMPUTATION

COMP

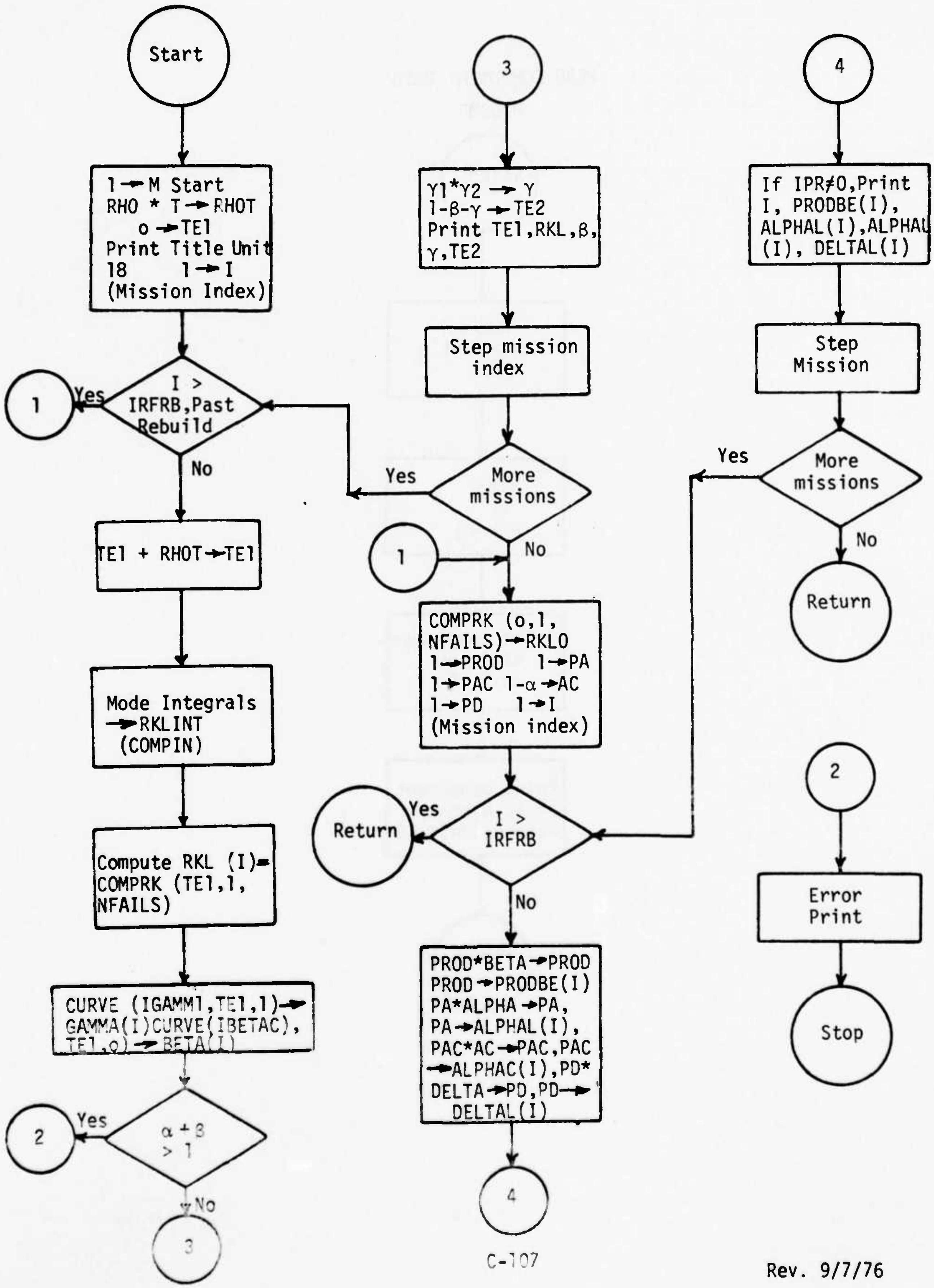


READ COMPONENT DATA

RDCOMP



INITIALIZE EQUIPMENT DATA
INIT2



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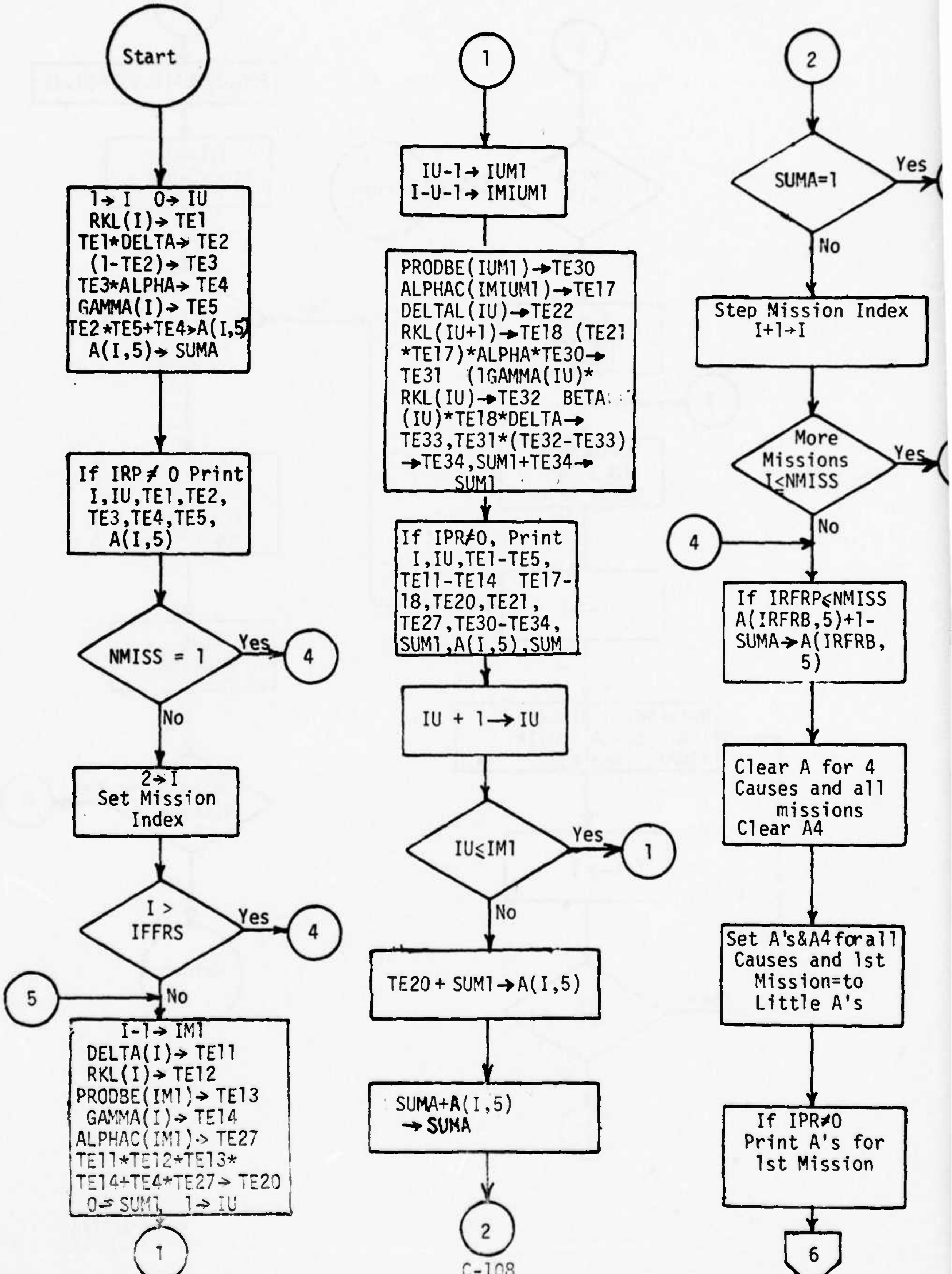
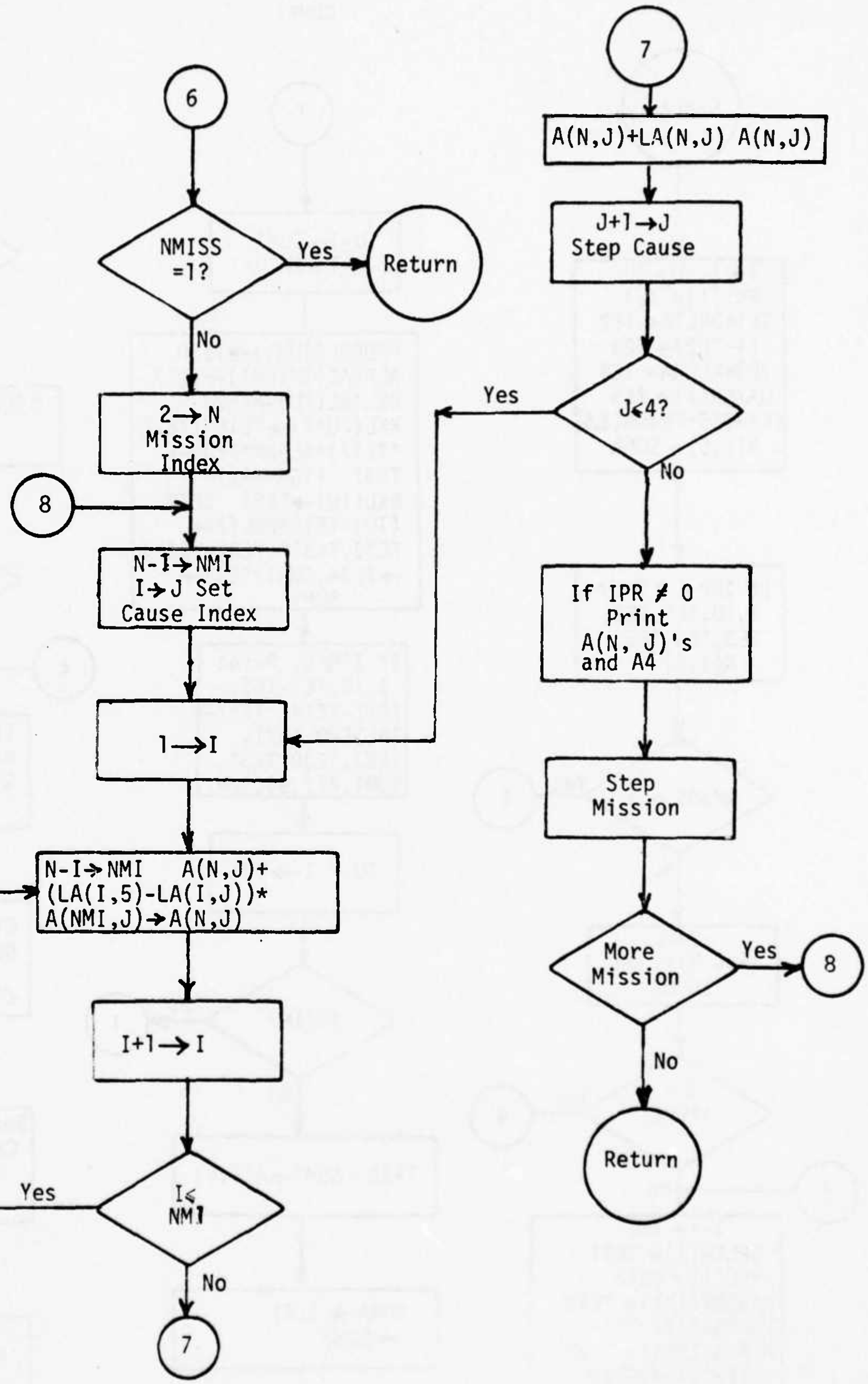
COMPUTE A

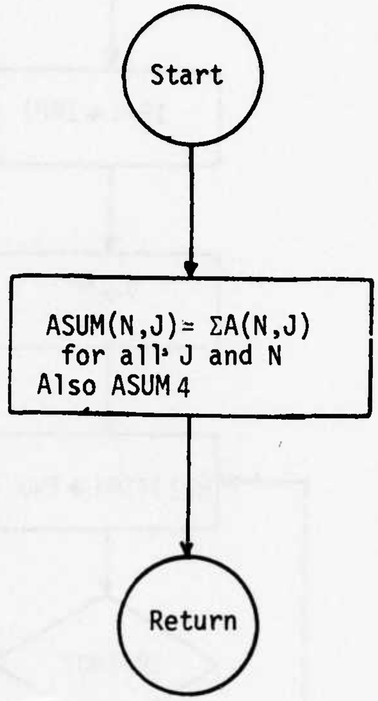
COMP1




6
NMISS =1?
Yes
Return
No
2→N Mission Index
8
N-I→NMI I→J Set Cause Index
1→I
N-I→NMI A(N,J)+ (LA(I,5)-LA(I,J))* A(NMI,J)→A(N,J)
I+1→I
I≤ NMI
Yes
No
7
7
A(N,J)+LA(N,J) A(N,J)
J+1→J Step Cause
J≤4?
Yes
No
If IPR ≠ 0 Print A(N, J)'s and A4
Step Mission
More Mission
Yes
8
No
Return

THE SUM OF THE A'S

COMP2



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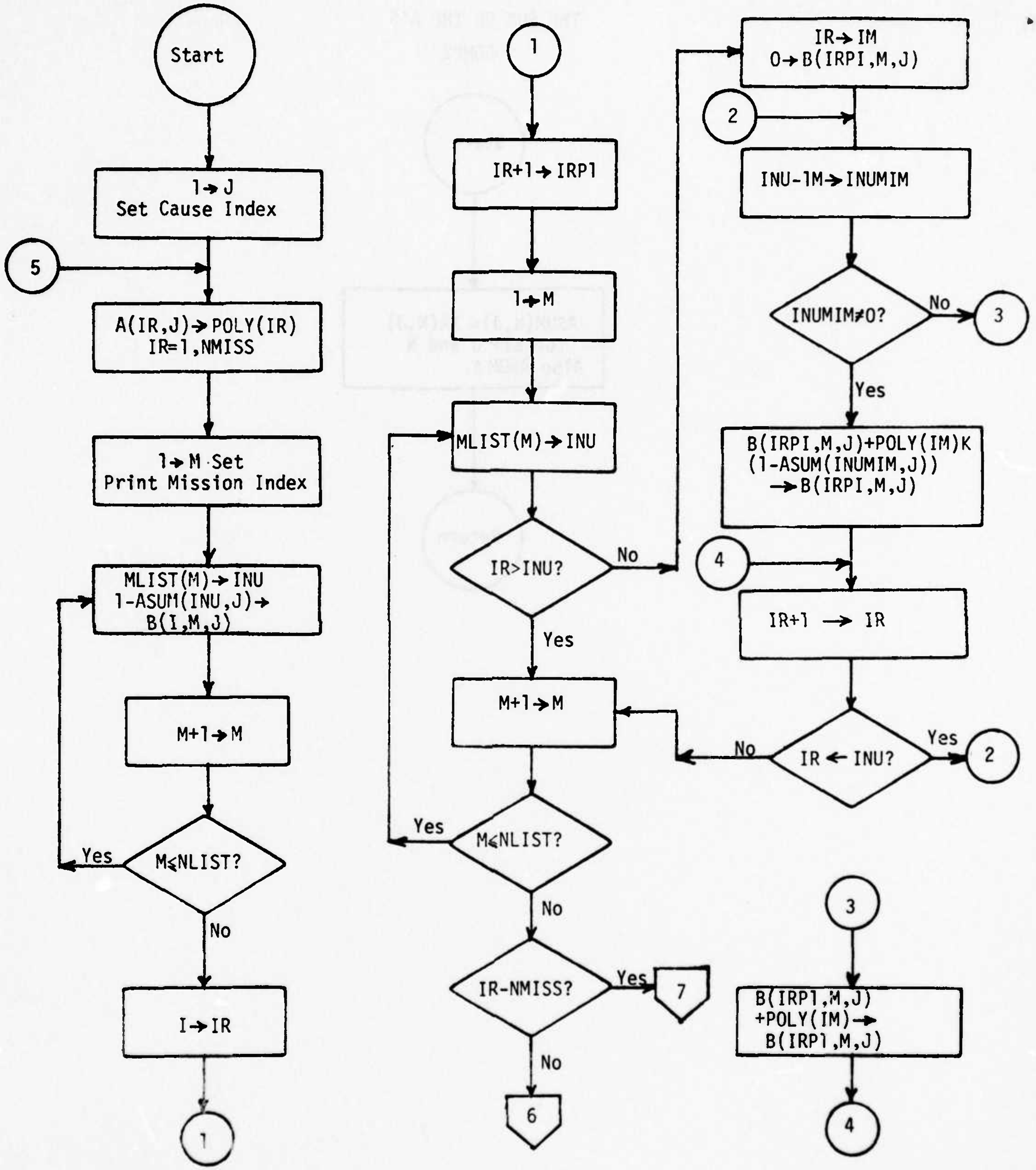
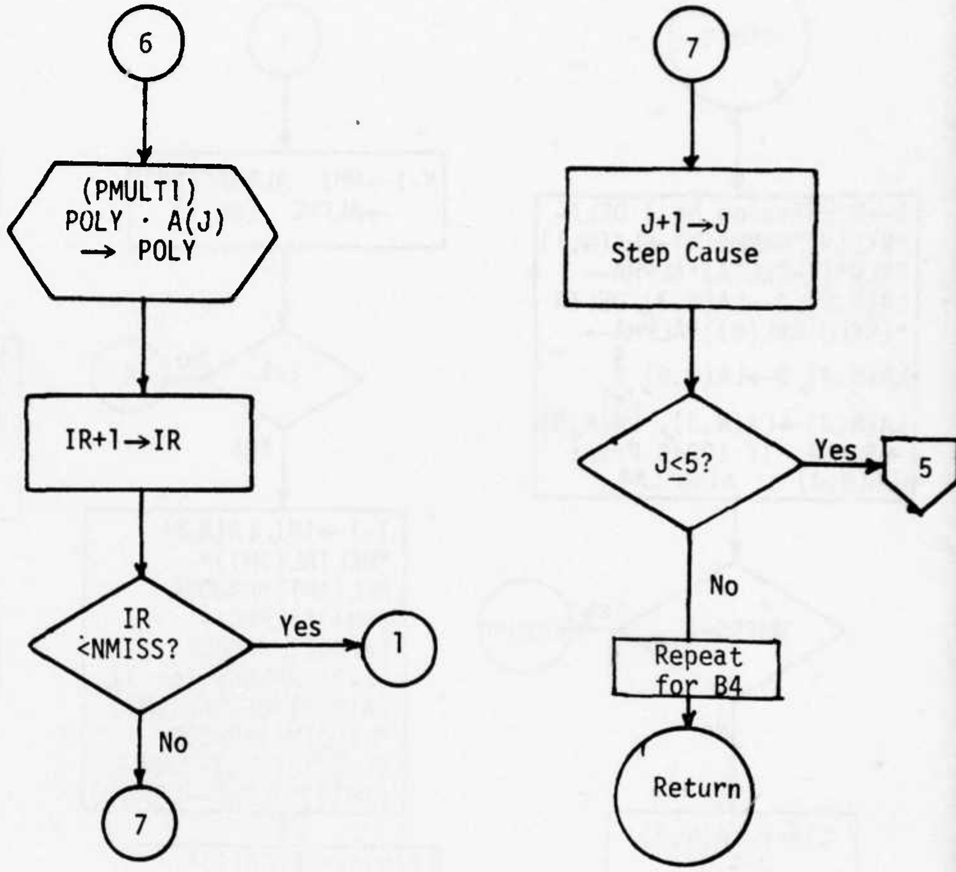
COMPUTE THE B's

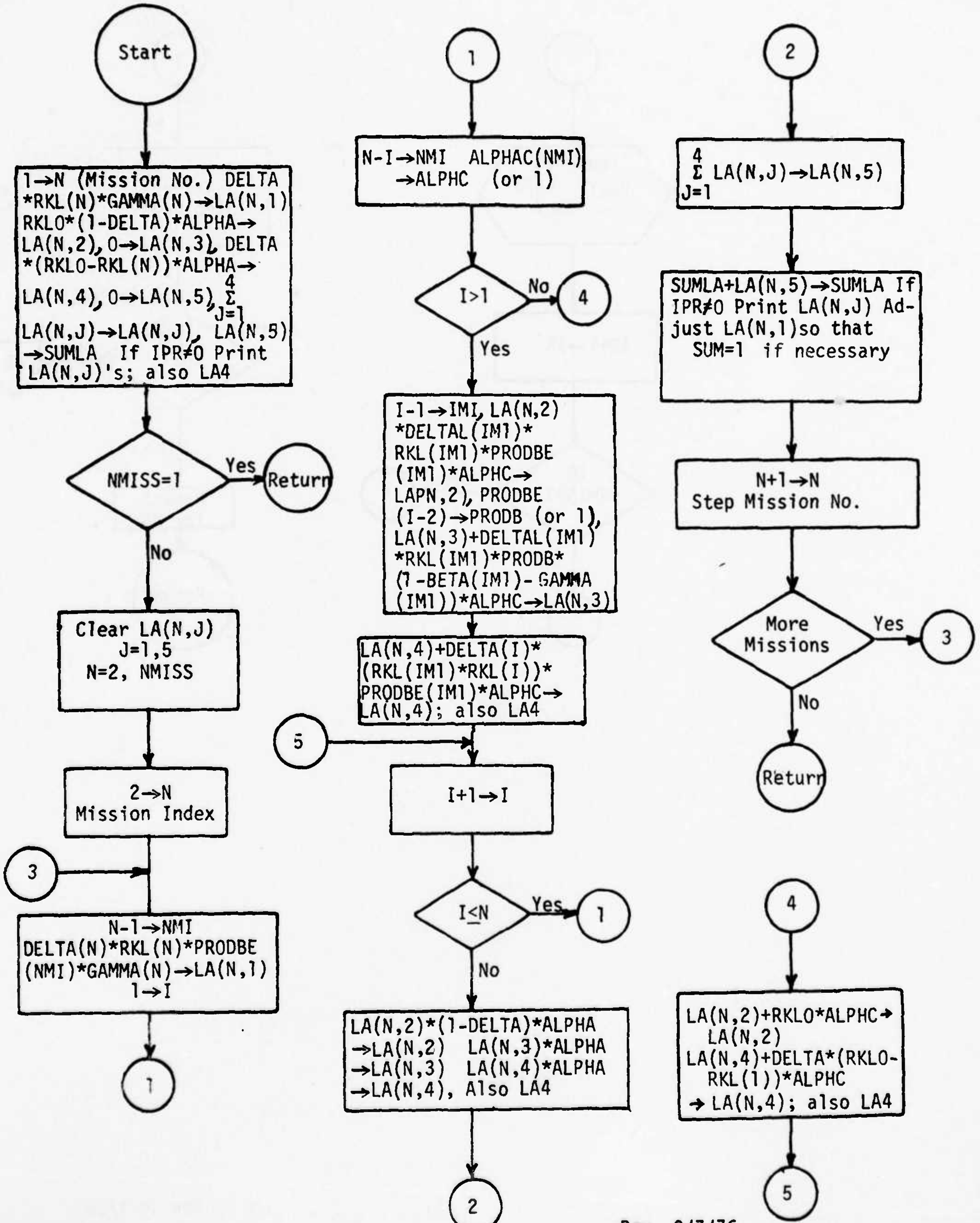
COMP3




6
(PMULTI)
POLY · A(J)
→ POLY
IR+1→IR
IR
<NMISS?
Yes
1
No
7
7
J+1→J
Step Cause
J≤5?
Yes
5
No
Repeat
for B4
Return

COMPUTE THE LITTLE A's

COMP4



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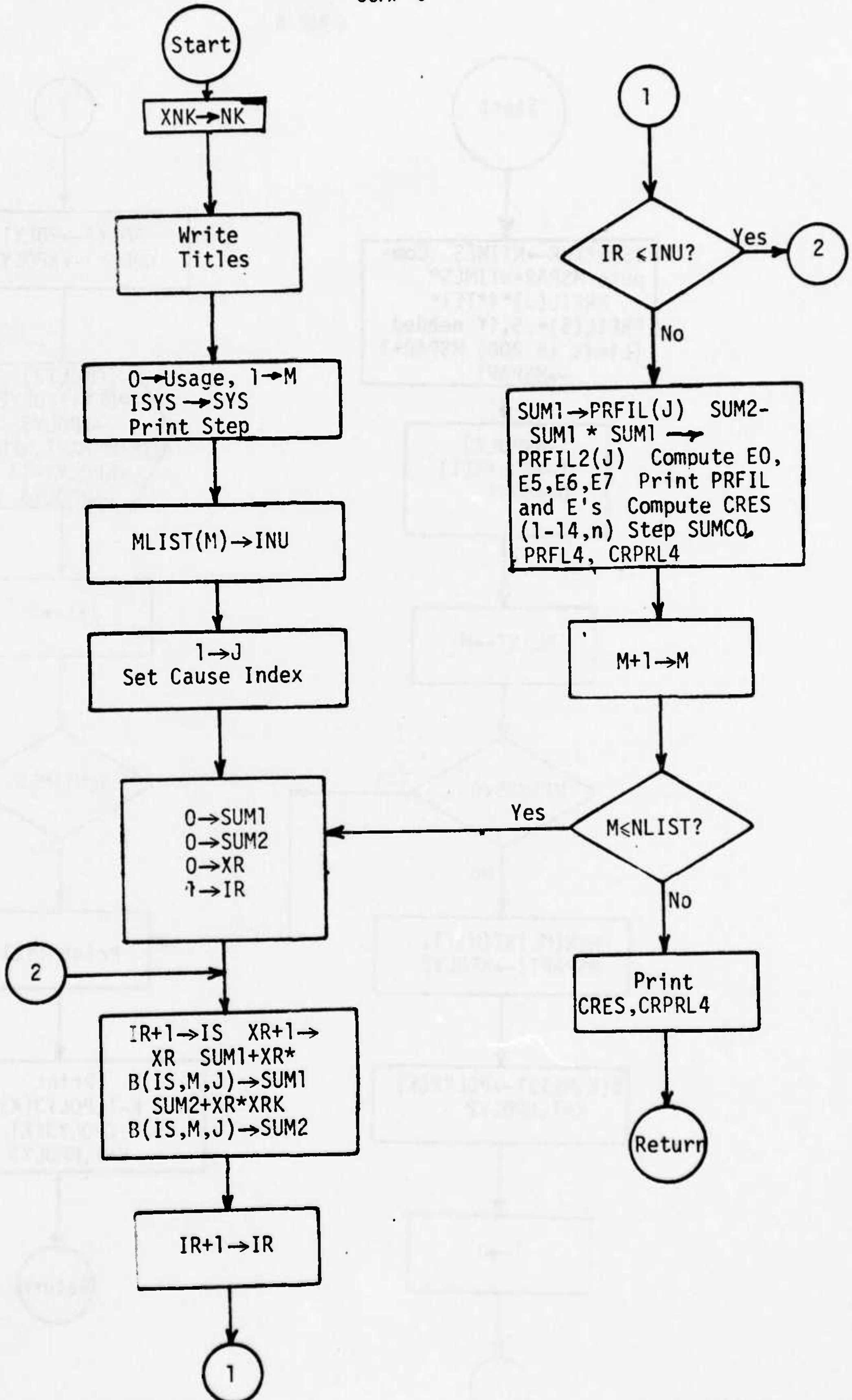
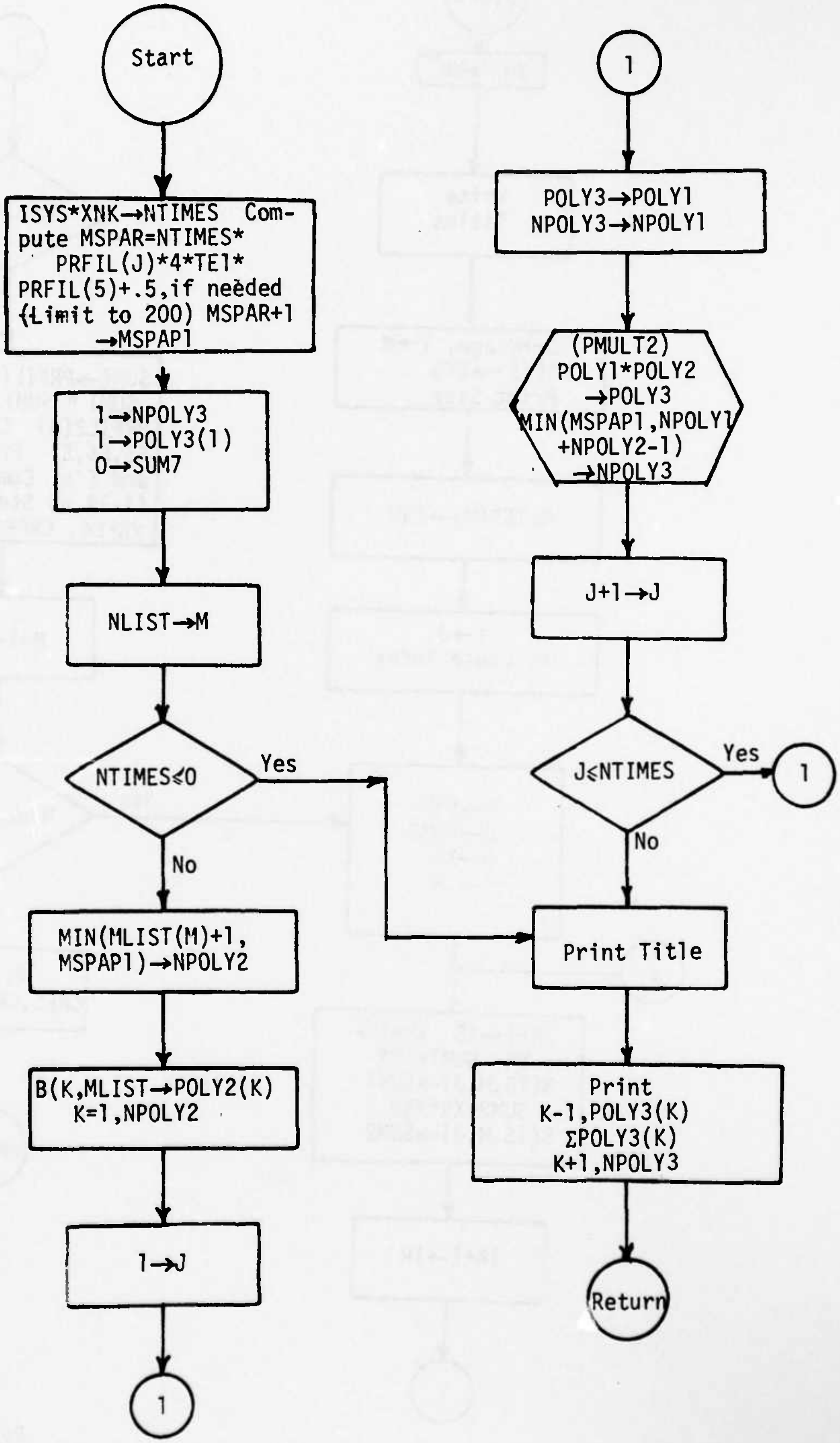
COMPUTE THE EQUIPMENT RESULTS

COMP 5



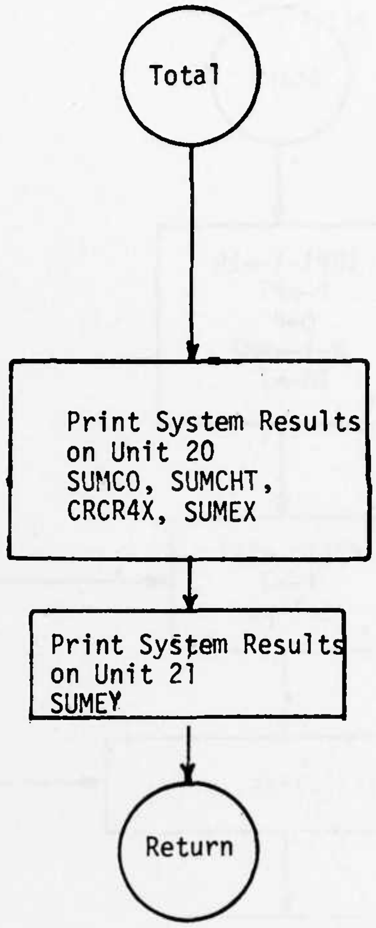
COMPUTE SPARES PROBABILITIES

COMP 6



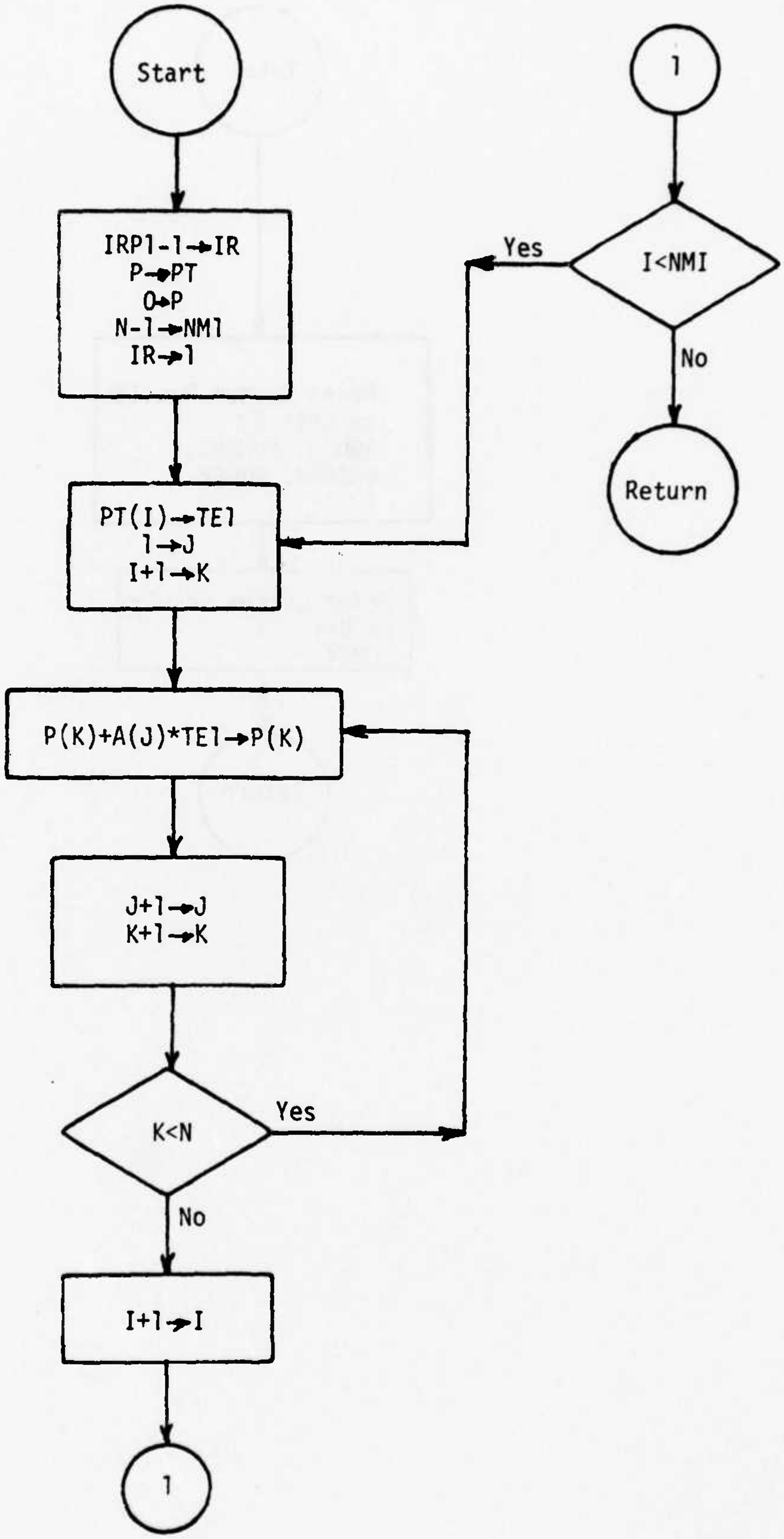
PRINT SYSTEM RESULTS

PRTOT



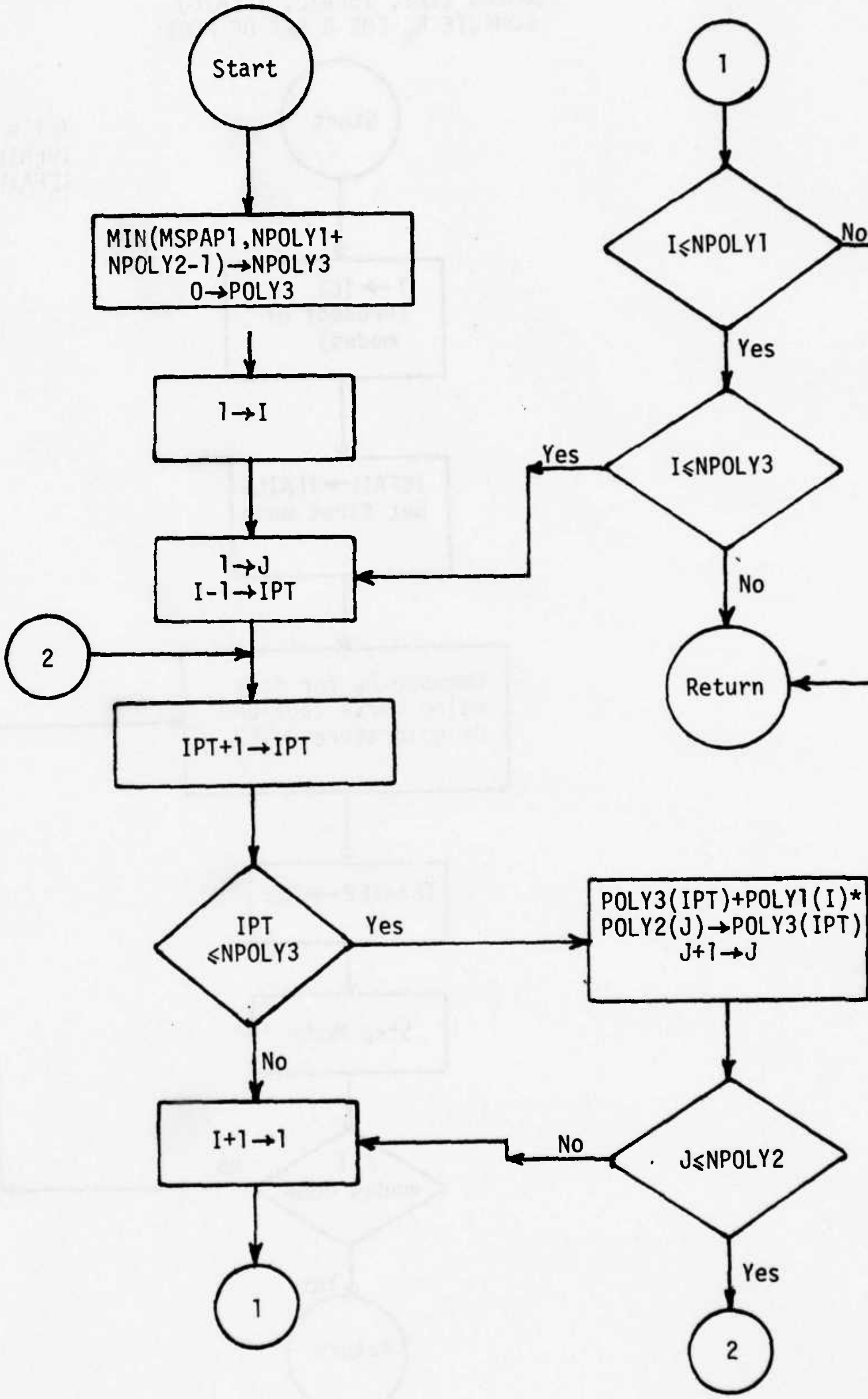
MULTIPLY TWO POLYNOMIALS WITH NO CONSTANT

PMULT1 (P, A, N, IRP1)

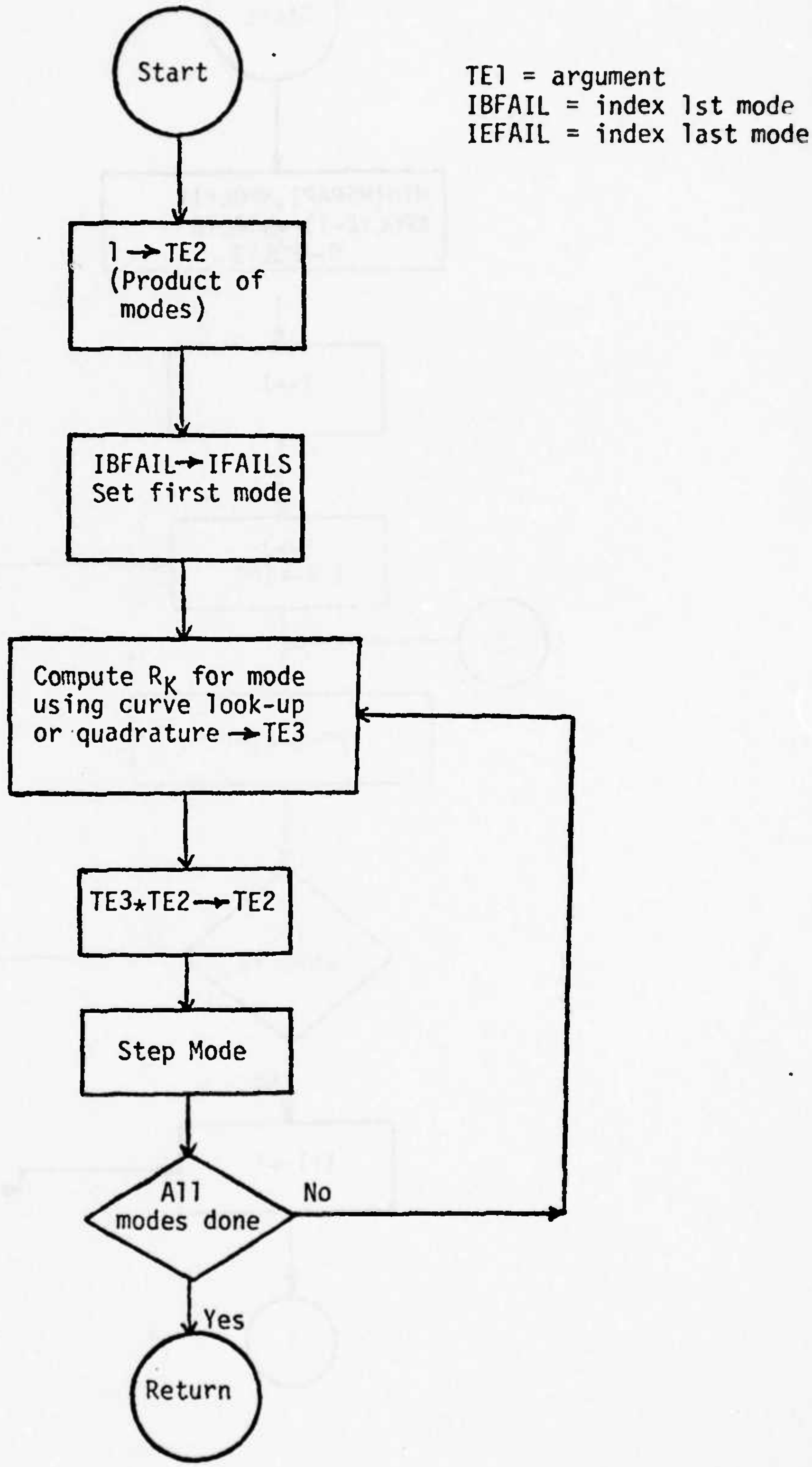


MULTIPLY TWO POLYNOMIALS

PMULT2



COMPRK (TE1, IBFAIL, IEFAIL)
COMPUTE R_K FOR A SET OF MODES



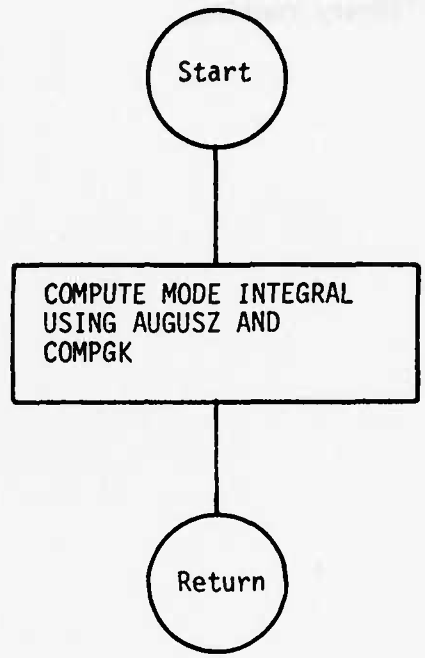
Additional 9/7/76

AUGAUS (A,B,R,S,J,F,RP)
GAUSSIAN QUADRATURE

This is a standard ORI library routine.

COMPIN (BIN, BFI, IB)
Compute Mode Integral

BIN = lower limit
BFI = upper limit
IB = mode

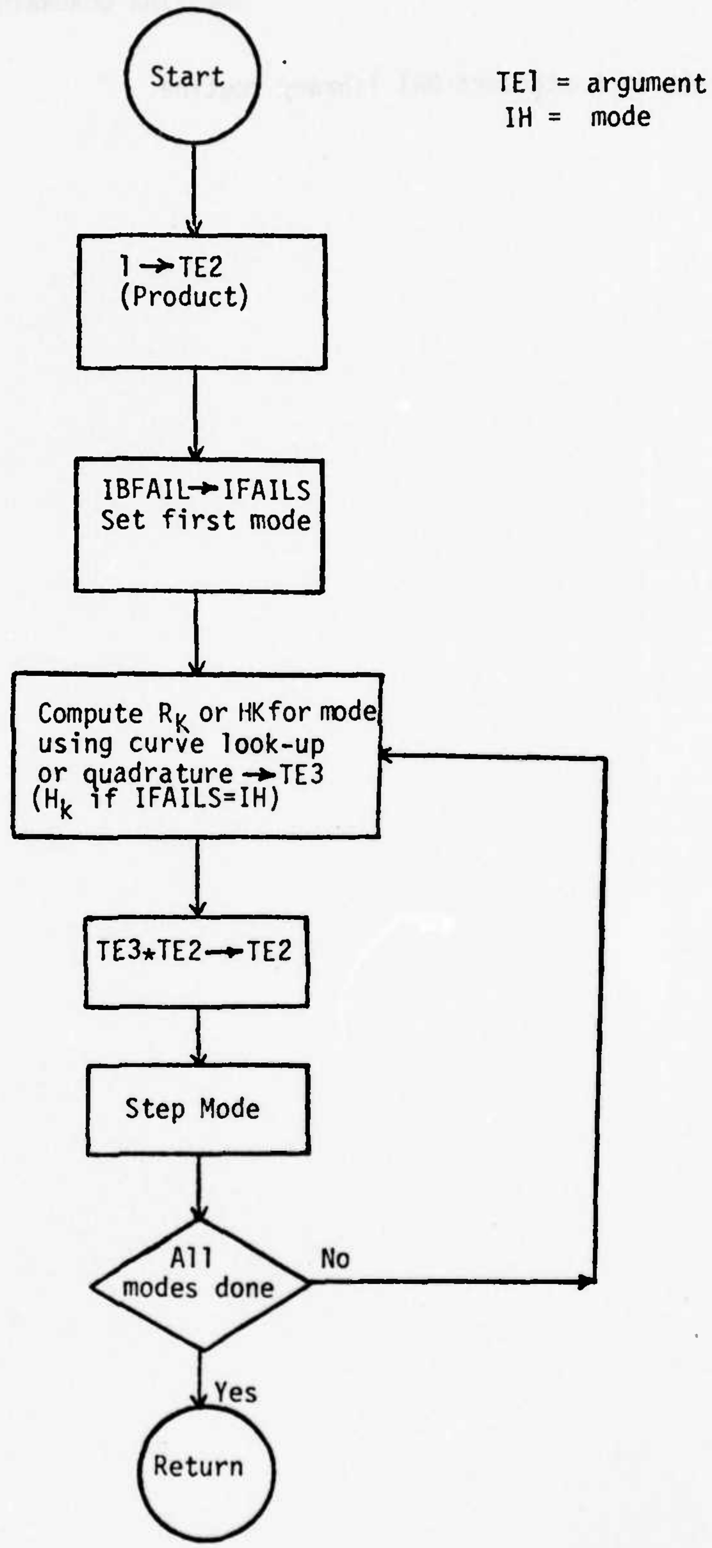


Additional 9/7/76

AUGUSZ (A,B,R,S,J,F,RP)
GAUSSIAN QUADRATURE

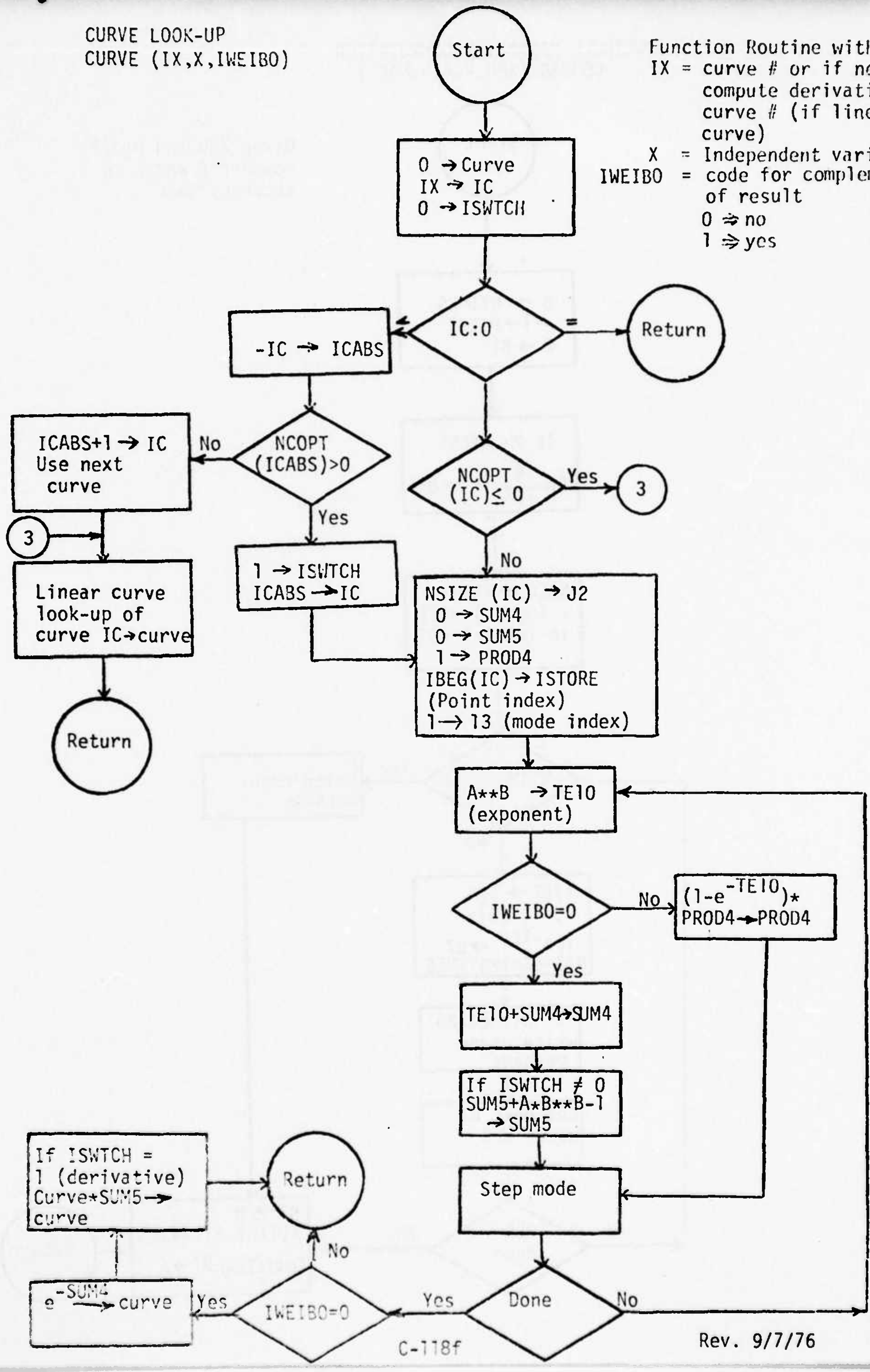
This is a standard ORI library routine.

COMPGK (TE1,IH)
COMPUTE INTEGRAND FOR MODE INTEGRAL



CURVE LOOK-UP
CURVE (IX,X,IWEIBO)

Function Routine with
IX = curve # or if negative compute derivative of curve # (if linear next curve)
X = Independent variable
IWEIBO = code for complement of result
0 ⇒ no
1 ⇒ yes



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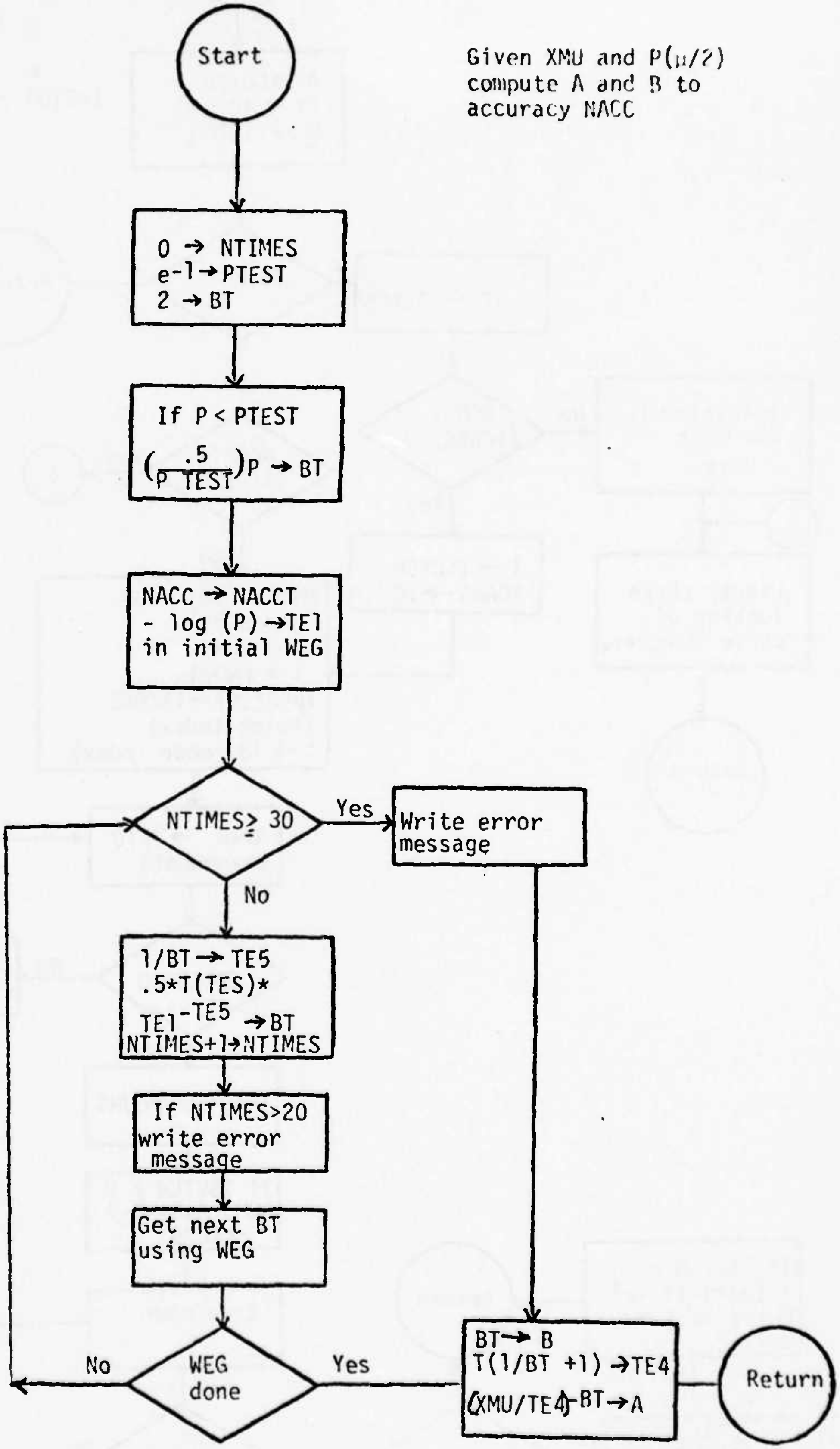
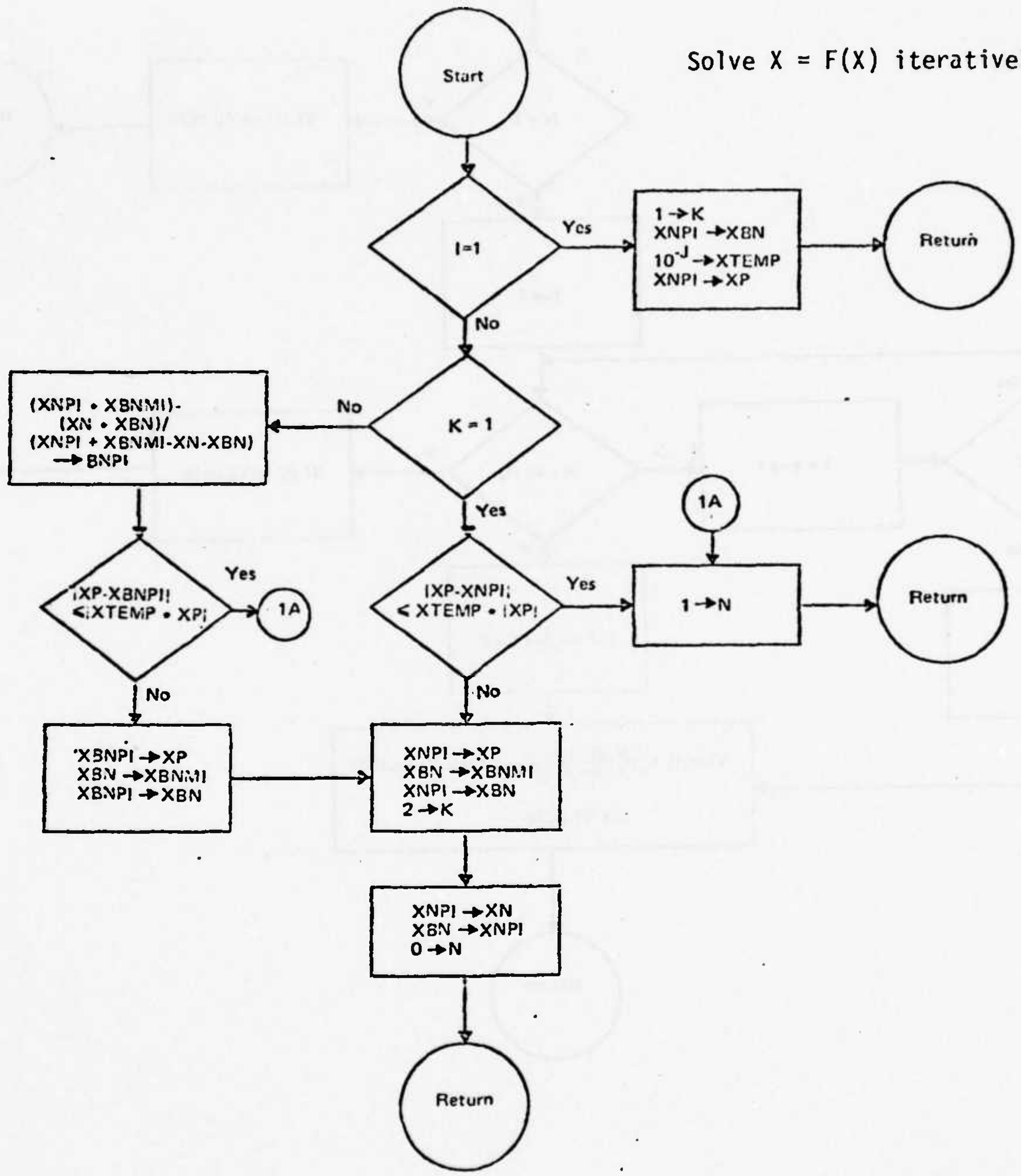
WEIBULL PARAMETER COMPUTATION
COMPAB (XMU,P,A,B,NACC)



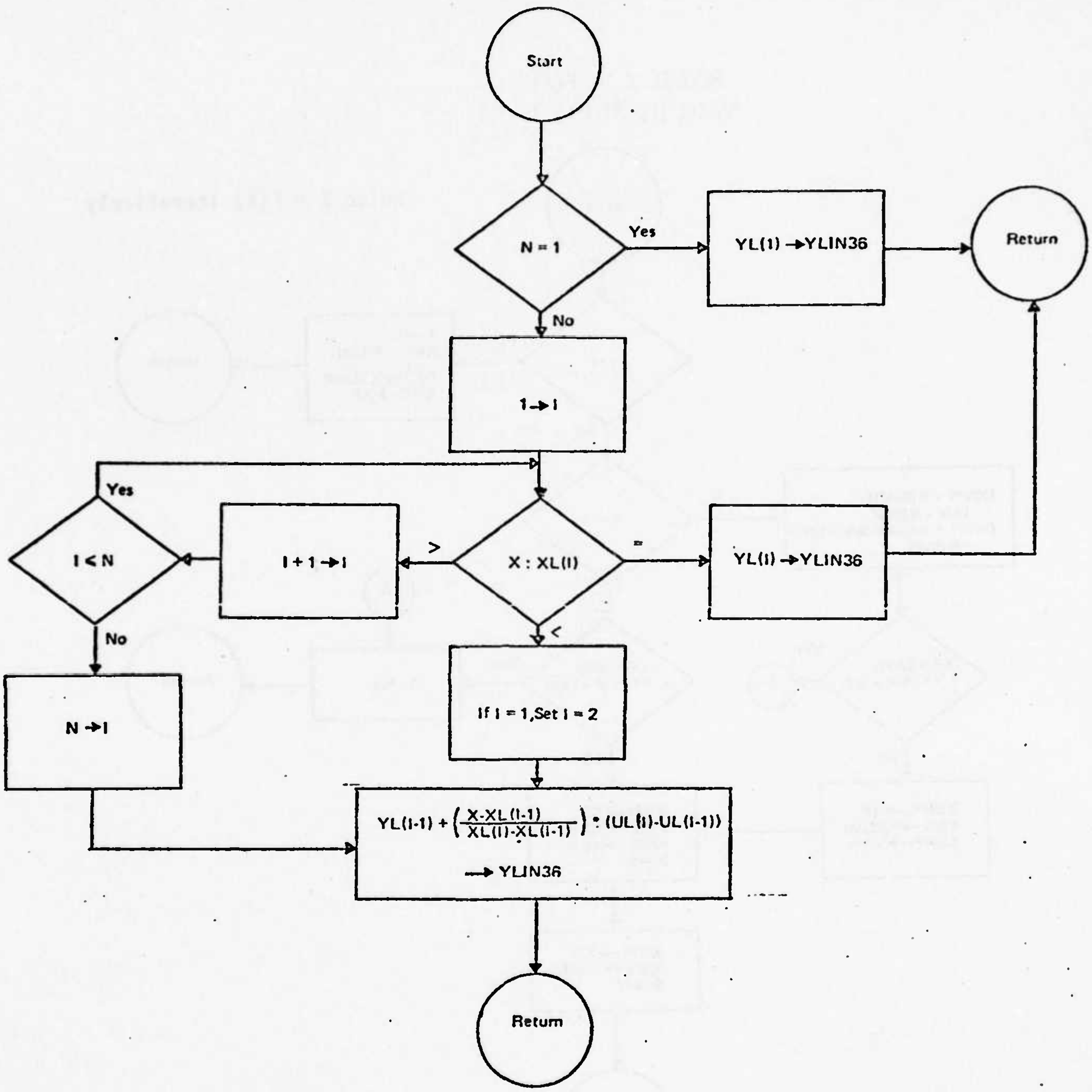
SOLVE X = F(X)
WEG (I, XNPI, J, N)

Solve X = F(X) iteratively



 Additional 9/7/76

LINEAR CURVE LOOK-UP
YLIN36 (N, XL, YL, X)



PROGRAM LISTINGS
FOR COST/SPARES MODEL

```
FORTRAN IV G LEVEL  21                MAIN              DATE = 76246         18/16/46              PAGE 0001

                C        MAIN PROGRAM VERSION 4 REVISED COST-SPARES MODEL        ZUSMAN/COOK
                C                    ONE MISSION TYPE ONLY           MARCH 1976
                C        WITH FAILURE CAUSES
 0001                 IMPLICIT REAL * 4(A-H,C-Z)
                C        CURVE INPUTS   FROM UNIT 9
 0002                 CALL CURVIN
                C     MAIN INPUTS
                C           READ SYSTEM AND MISSION DATA
 0003               1 CALL INPUTI
                C           INITIALIZE SYSTEM TOTALS AND PRINTS
 0004                 CALL INIT
                C        CONTROL FOR COMPUTATION FOR ALL TYPES AND MISSIONS
 0005                 CALL CCMP
                C        COMPUTE AND PRINT SYSTEM TOTALS
 0006                 GOTO 1
 0007                 END
```

```
0001          SUBROUTINE CURVIN
        C                   READ INPUT CURVES FROM UNIT 9
0002          IMPLICIT REAL * 4 (A-H,O-Z)
0003          REAL * 4 LA,LA4,LA4SUM
0004          COMMON T,TAU,XMAR
0005          COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
0006          COMMON WEIBA(400),WEIBB(400)
0007          COMMON XNK,XXK,XXKP
0008          COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,           CAPT,DELTT,XIT
0009          COMMON SUMBAC,SUMBAV,SUMBRF,OMEGA(2)
0010          COMMON AC,AV,RF
0011          COMMON RHOT,RKL(100 ),BETA(100 ),XAMMA(100  )
0012          COMMON RKLO,SSLIFE,EPS,GAMMA2
0013          COMMON PRODBE(100),A(100,5),ASUM(100,5)
0014          COMMON HK(5),CK(9),SUMCO(14,10),CRES(14,10),CAUSE( 4,5)
0015          COMMON POLY(100),PRFIL1(5),PRFIL2(5)
0016          COMMON POLY1(201),POLY2(201),POLY3(201)
0017          COMMON B(10,10,5)
0018          COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
0019          COMMON ITLE(20),NMISS,IOPT1,NTYPES,IPR,    NLIST,MLIST( 10),MSTART
0020          COMMON MISNAM(10),MISDES(20,5)
0021          COMMON I,IM1,ITYPES
0022          COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
0023          COMMON IBEG(100),IENAME(4),ICNAME(4)
0024          COMMON NFAILS,IVENC1(10),IVENC2(10),MODTYP(10)
0025          COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
0026          COMMON IRFRB,ICYC,ICYCM1,JDEL1,JMAXI,JDEL2
0027          COMMON IREAD,IWRITE,IFUNAM(4)
0028          COMMON ISYS,     NMISP1,MSPAR,MSPAR1
0029          COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
0030          COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
0031          COMMON PRFL4(10), HK4(10),   B4(10,10,10),A4(100,10),ASUM4(100,10)
0032          COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
0033          COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
0034          COMMON CRPRL4(5),SUMEX(12,10),SUMEY(6,10)
0035          XMAX1 = .15
0036          IMAX3 = 100
0037          IERR = 0
0038          ISTORE = 0
0039          ISTOMX = 400
0040          READ (9,101,END=96) NCURVE
0041          WRITE (6,201) NCURVE
0042          IF (NCURVE - IMAX3)  11,11,99
0043       11 CONTINUE
0044          DO 1 I1=1,NCURVE
0045          READ (9,102) NSIZE(I1),NCOPT(I1),NACC(I1),(CURNAM(K,I1),K=1,10)
0046          WRITE (6,202) (I,NSIZE(I1),NCOPT(I1),NACC(I1),
             *    (CURNAM(K,I1),K=1,10)
0047          IC2 = NCOPT(I1)
0048          IF (IC2 .LT. 0 .OR. IC2 .GT. 2)  GO TO 95
0049          NACD = NACC(I1)
0050          I2 = NSIZE(I1)
0051          ITEST = ISTORE + I2
0052          IF (ITEST .GT. ISTOMX)  GO TO 98
0053          IBEG(I1) = ISTORE + 1
0054          DO 2 I3=1,I2
```

```
      ISTORE = ISTORE + 1
      READ (9,103) CURVEX(ISTORE),CURVEY(ISTORE),(POINAM(K,ISTORE),
     *  K=1,10)
      WRITE (6,203) I3,ISTORE,CURVEX(ISTORE),CURVEY(ISTORE),
     *    (POINAM(K,ISTORE),K=1,10)
      IF (IC2)  2,2,3
    3 CONTINUE
      IF (IC2 .EQ. 1)  GO TO 31
      NCOPT(I) = 1
      WEIBA(ISTORE) = CURVEX(ISTORE)
      WEIBB(ISTORE) = CURVEY(ISTORE)
      TE1 = (1./WEIBB(ISTORE)) + 1.
      TE2 = GAMMA(TE1)
      CURVEX(ISTORE) =TE2*(WEIBA(ISTORE)**(-1./WEIBB(ISTORE)))
      CURVEY(ISTORE) =EXP(-((TE2/2.)**WEIBB(ISTORE)))
      WRITE (6,205) CURVEX(ISTORE),CURVEY(ISTORE)
      GO TO 2
   31 CONTINUE
      IF (CURVEY(ISTORE) - XMAX1)  97,13,13
   97 WRITE (6,303) CURVEY(ISTORE),XMAX1
      IERR = IERR + 1
   13 CONTINUE
      IF (CURVEY(ISTORE) .NE. .60656)  GO TO 21
      WEIBA(ISTORE) = 1./CURVEX(ISTORE)
      WEIBB(ISTORE) = 1.
      GO TO 22
   21 CONTINUE
      CALL COMPAR(CURVEX(ISTORE),CURVEY(ISTORE),WEIBA(ISTORE),
     *     WEIBB(ISTORE),NACC)
   22 CONTINUE
      WRITE (6,204) WEIBA(ISTORE),WEIBB(ISTORE)
    2 CONTINUE
    1 CONTINUE
      IF (IERR .GT.  0)  STOP
      RETURN
   99 WRITE (6,301) NCURVE,IMAX2
      STOP
   95 WRITE (6,305)
      STOP
   98 WRITE (6,302) ISTOPX
      STOP
   96 WRITE (6,304)
      STOP
  101 FORMAT (I10)
  102 FORMAT (I10,I10,I10,10X,10A4)
  103 FORMAT (10X,2F10.0,10X,10A4)
  201 FORMAT (7H1NCURVE,I10)
  202 FORMAT (6H0CURVE,I5,5X,6HNSIZE=,I5,5X,6HNCOPT=,I5,5X,5HNACC=,
     *   I5,5X,10A4)
  203 FORMAT (10X,5HPOINT,I5,2X,6HISTORE,I5,2X,7HCURVEX=,G16.8,2X,
     *    7HCURVEY=,G16.8,2X,10A4)
  204 FORMAT (25X,2HA=,G16.8,10X,2HB=,G16.8)
  205 FORMAT (25X,3HMU=,G16.8,10X,9HP(MU/2)=,G16.8)
  301 FORMAT (15H0NCURVE TOO BIG,2I10)
  302 FORMAT (19H0NO ROOM FOR CURVES,I10)
  303 FORMAT (12H0P TOO SMALL,2G16.8)
```

```
0106        304 FORMAT (14H0NO CURVE DATA/)
0107        305 FORMAT (19H0NCOPT OUT OF RANGE/)
0108            END
```

```
0001          SUBROUTINE INPUT1
        C             MAIN INPUTS
        C                   TITLE AND MISSION DATA
0002          IMPLICIT REAL * 4 (A-H,C-Z)
0003          REAL * 4 LA,LA4,LA4SUM
0004          COMMON T,TAU,XMAR
0005          COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
0006          COMMON WEIBA(400),WEIPB(400)
0007          COMMON XNK,XXK,XXKF
0008          COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,         CAPT,DELTT,XIT
0009          COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
0010          COMMON AC,AV,RE
0011          COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100  )
0012          COMMON RKLO,SSLIFE,EPS,GAMMA2
0013          COMMON PRODBE(100),A(100,5),ASUM(100,5)
0014          COMMON HK(5),CK(9),SUMCC(14,10),CRES(14,10),CAUSE( 4,5)
0015          COMMON POLY(100),PREDL(5),PREDL2(5)
0016          COMMON POLY1(201),POLY2(201),POLY3(201)
0017          COMMON B(101,10,5)
0018          COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
0019          COMMON ITLE(20),NMISS,ICPT1,NTYPES,IPR,   NLIST,MLIST( 10),MSTART
0020          COMMON MISNAM(10),MISCES(20,5)
0021          COMMON I,IM1,ITYPES
0022          COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
0023          COMMON IBEG(100),IENAME(4),ICNAME(4)
0024          COMMON NFAILS,IVENO1(10),IVENO2(10),MODTYP(10)
0025          COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
0026          COMMON IRERB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
0027          COMMON IREAD,IWRITE,IFUNAM(4)
0028          COMMON ISYS,    NMISP1,MSPAR,MSPAP1
0029          COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
0030          COMMON LA(100,5),LA4(100,10),LA4SUM(100),PKLINT(100,10)
0031          COMMON PREL4(10), HK4(10),  B4(101,10,10),A4(100,10),ASUM4(100,10)
0032          COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
0033          COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
0034          COMMON CRPRL4(5),SUMEX(12,10),SUMEY(6,10)
0035          DIMENSION CAUSEX( 4,5)
0036          DATA CAUSEX/4HPREV,4HENTI,4HON  ,4H    ,
             *            4HHAND,4HLING,4H    ,4H    ,
             *            4HINDU,4HCED ,4HFAIL,4HURE ,
             *            4HMISS,4HION ,4HFAIL,4HURE ,
             *            4HALL ,4H    ,4H    ,4H    /
0037          DO 1  J=1,5
0038          DO 1  K=1,4
0039        1 CAUSE(K,J)=CAUSEX(K,J)
0040          IMAX1 = 100
0041          READ (5,101,END=99) (ITLE(M),M=1,19),IPR
0042          WRITE (6,201) (ITLE(M),M=1,19),IPR
0043          READ  (5,102)  NMISS,T,  TAU,EPS,   (MISNAM(K),K=1,10)
0044          NT = 2
0045          WRITE (6,202)  NMISS,T,  TAU, EPS,  (MISNAM(K),K=1,10)
0046          IF (NMISS - IMAX1)  11,11,98
0047       11 CONTINUE
0048          NMISP1 = NMISS + 1
0049          SSLIFE = NMISS * (T+TAU)
0050          XMAR = NMISS/SSLIFE
```

```
      READ (5,107)  ((MISDES(K,J),K=1,20),J=1,5)
      WRITE (6,207) ((MISDES(K,J),K=1,20),J=1,5)
      READ (5,103)   JDEL1,JMAX1,JDEL2,ISYS,NCRIT
      WRITE (6,203)  JDEL1,JMAX1,JDEL2,ISYS,NCRIT
C              PRINT SYSTEM AND MISSION SUMMARY FOR REPORT 18
      WRITE (18,501) (TITLE(M),M=1,19)
      WRITE (18,502) (MISNAM(K),K=1,10),AMISS,T,TAU
      WRITE (18,503) SSLIFE
      WRITE (18,504) XMAR
      WRITE (18,506) ISYS
      WRITE (18,505) ((MISDES(K,J),K=1,20),J=1,5)
      RETURN
   99 STOP
   98 WRITE (6,301) NMISS,IMAX1
      STOP
   97 WRITE (6,302) NLIST,IMAX1
      STOP
  101 FORMAT (19A4,I4)
  102 FORMAT (I5,F5.0,     F5.0,F10.0,15X,10A4)
  103 FORMAT (5I5)
  104 FORMAT (5F10.0)
  106 FORMAT (F10.0)
  107 FORMAT (20A4)
  201 FORMAT (36H1VERSION 4 REVISED COST/SPARES MODEL//10X,19A4,5X,
     *    4HIPR=,I5/)
  202 FORMAT (7H NMISS=,I5,5X,2HT=,F10.3,
     1                                5X,4HTAU=,F10.3,1X,
     3     4HEPS=,F12.8,1X,7HMISNAM=,10A4)
  203 FORMAT(26H0MISSION PRINT RESULT DATA,1X,7H JDEL1=,I5,7H JMAX1=,
     *    I5,7H JDEL2=,I5,6H ISYS=,I5,1X,6HNCRIT=,I5)
  204 FORMAT (8H MISSION,8X,1HT,7X/(I8,G16.8))
  206 FORMAT (8H SSLIFE=,F10.1)
  207 FORMAT (7H0MISDES/(20X,20A4))
  301 FORMAT (14H0NMISS TOO BIG,2I10)
  302 FORMAT (14H0NLIST TOO BIG,2I10)
  304 FORMAT (19H0NLIST REDUCED BY ,I10)
  501 FORMAT (1H1,50X,36HAMSEC SYSTEM AND MISSION DESCRIPTION//
     *     25X,19A4/)
  502 FORMAT (1H0,4X,12HMISSION NAME,38X,10A4/
     1    1H0,4X,18HNUMBER OF MISSIONS,32X,I10/
     2    1H0,4X,21HMISSION LENGTH(HOURS),29X,F10.2/
     3    1H0,4X,21HTIME BETWEEN MISSIONS,29X,F10.2)
  503 FORMAT (1H0,4X,33HSYSTEM SERVICE LIFE (CLOCK HOURS),17X,F10.2)
  504 FORMAT (1H0,4X,42HMISSION ARRIVAL RATE (MISSION/CLOCK HOURS),
     *    8X,F10.3)
  505 FORMAT (1H0,4X,20A4)
  506 FORMAT (1H0,4X,22HNUMBER OF SYSTEMS USED,28X,I10)
      END
```

```
      SUBROUTINE INIT
C          INITILIAZE SYSTEM TOTALS AND PRINT OF RESULTS
      IMPLICIT REAL * 4 (A-H,O-Z)
      REAL * 4 LA,LA4,LA4SUM
      COMMON T,TAU,XMAR
      COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON XNK,XXK,XXKP
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRF,OMEGA(2)
      COMMON AC,AV,RE
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100  )
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON PRODBE(100),A(100,5),ASUM(100,5)
      COMMON HK(5),CK(9),SUMCO(14,10),CRES(14,10),CAUSE( 4,5)
      COMMON POLY(100),PRFIL(5),PRFIL2(5)
      COMMON POLY1(201),POLY2(201),POLY3(201)
      COMMON B(101,10,5)
      COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
      COMMON ITLE(20),NMISS,ICPT1,NTYPES,IPR,   NLIST,MLIST( 10),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),ICNAME(4)
      COMMON NFAILS,IVENC1(10),IVENO2(10),MODTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IREFB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      COMMON ISYS,      NMISP1,MSPAR,MSPAP)
      COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
      COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
      COMMON PRF(4)10), HK4(10),   B4(101,10,10),A4(100,10),ASUM4(100,10)
      COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
      COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
      COMMON CRPRL4(5),SLMEX(12,10),SUMEY(6,10)
      NLIST = 0
      DO 4  I=1,NMISS
      IF (NLIST .EQ. 10)  GO TO 5
      IF (I .EQ. 1)  GO TO 11
      IF (I .LE. JMAX1 .AND. (I-1)/JDEL1)*JDEL1 .EQ. 0)  GO TO 11
      IF (I .GE. JMAX1 .AND. (I-1)/JDEL2)*JDEL2 .EQ. 0)  GO TO 11
      GO TO 4
   11 NLIST = NLIST + 1
      MLIST(NLIST) = I
    4 CONTINUE
    5 CONTINUE
      IF (NLIST .EQ. 10)  GO TO 13
      IF (MLIST(NLIST) .EQ. NMISS)  GO TO 14
      NLIST = NLIST + 1
      MLIST(NLIST) = NMISS
      GO TO 14
   13 MLIST(NLIST) = NMISS
   14 CONTINUE
      DO 12  M=1,NLIST
      DO 15  I=1,14
      SUMCO( I),M) = 0.
```

```
   15 CONTINUE
      DO 16  ICRIT = 1,NCRIT
      CRCR47(M,ICRIT) = 0.
      CRCR48(M,ICRIT) = C.
      CRCR49(M,ICRIT) = 0.
   16 CONTINUE
      DO 17  I=1,3
   17 SUMCHT(I,M) = 0.
      DO 18  I=1,12
      SUMEX(I,M) = 0.
   18 CONTINUE
      DO 19  I=1,6
      SUMEY(I,M) = 0.
   19 CONTINUE
   12 CONTINUE
      RETURN
      END
```

```
0001            SUBROUTINE COMP
          C        CONTROL FOR COMPUTATION FOR ALL TYPES AND MISSIONS
0002            IMPLICIT REAL * 4 (A-H,O-Z)
0003            REAL * 4 LA,LA4,LA4SUM
0004            COMMON T,TAU,XMAR
0005            COMMON CURVEX(400(,CURVEY(400(,POINAM(10,400),CURNAM(10,100(
0006            COMMON WEIPA(400(,WEIBR(400)
0007            COMMON XNK,XXK,XXKP
0008            COMMON ALPHA,RHO,DELTA,UNIT(5(,SUMT,          CAPT,DELTT,XIT
0009            COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2(
0010            COMMON AC,AV,RE
0011            COMMON RHOT,RKL(100 ),BETA(100 (,GAMMA(100  (
0012            COMMON RKLO,SSL(FE,EPS,GAMMA2
0013            COMMON PRODBE(100(,A(100,5),ASUM(100,5)
0014            COMMON HK(5(,CK(9),SUMCC(14,10),CRES(14,10(,CAUSE( 4,5(
0015            COMMON POLY(100(,PREFL(5(,PREFL2(5)
0016            COMMON POLY1(201(,POLY2(201(,POLY3(201(
0017            COMMON P(101,10,5(
0018            COMMON ALPHAL(100),ALPHAC(100(,DELTAL(100(
0019            COMMON ITLE(20),NMISS,ICPTI,NTYPES,IPR,   NLIST,MLIST( 10(,MSTART
0020            COMMON MISNAM(10(,MISDES(20,5(
0021            COMMON I,IM1,ITYPES
0022            COMMON NCURVE,NSIZE(100(,NCOPT(100(,NACC(100(
0023            COMMON IBEG(100(,IENAME(4),IGNAME(4(
0024            COMMON NFAILS,IVEND1(10(,IVEND2(10),MODTYP(10(
0025            COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
0026            COMMON IREFB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
0027            COMMON IREAD,IWRITE,IFUNAM(4(
0028            COMMON ISYS,    NMISP1,MSPAR,MSPAP1
0029            COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10(,SUMCHT(3,10(
0030            COMMON LA(100,5(,LA4(100,10(,LA4SUM(100(,RKLINT(10),10(
0031            COMMON PREL4(10(, HK4(10(,  B4(101,10,10(,A4(100,10(,ASUM4(100,10)
0032            COMMON CK3(10(,CK6(10(,CRES47(10,10(,CRES48(10,10(,CRES49(10,10(
0033            COMMON NCRIT,ICR(10(,CRCR47(10,5(,CRCR48(10,5(,CRCR49(10,5(
0034            COMMON CRPRL4(5),SUMEX(12,10(,SUMEY(6,10(
0035            WRITE (6,200) (ITLE(M(,M=1,19)
0036            READ (5,101( NTYPES
0037            WRITE (6,201( NTYPES
0038            DO 1  ITYPES=1,NTYPES
0039            CALL RDCOMF
          C        INITIALIZE EQUIPMENT FOR E COMPUTATION
0040            CALL INIT2
          C          COMPUTE LITTLE A'S FOR ALL MISSIONS AND ALL CAUSES
0041            CALL COMP4
          C         COMPUTE A  I=1,NMISS
          C                            FOR ALL CAUSES AND TOTAL
0042            CALL COMP1
          C         COMPUTE ASUM  I=1,NMISS
          C                            FOR ALL CAUSES AND TOTAL
0043            CALL COMP2
          C          COMPUTE  B  I=I,NMISPP1        FOR NLS IN MLIST
          C                            FOR ALL CAUSES AND TOTAL
0044            CALL COMP3
0045            IF ((PR .EQ. 0(  GO TO 52
0046            DO 51(  J=1,5
0047            WRITE ( 6,304( (CAUSE(K,J(,K=1,4 (
```

```
0048            WRITE ( 6,301)
0049            DO 2  I=1,NMISS
0050          2 WRITE ( 6,302) I,A(I,J),ASUM(I,J),P(I,MLIST,J)
0051            WRITE (6 ,303) NMISP1,B(NMISP1,MLIST,J)
0052         51 CONTINUE
0053         52 CONTINUE
          C        COMPUTE E FOR NUS IN MLIST FOR ALL CAUSES
0054            CALL COMP5
          C           COMPUTE SPARES   FOR NUS IN MLIST AND ISYS
0055            CALL COMP6
0056          1 CONTINUE
0057            CALL PRTOT
0058            RETURN
0059        101 FORMAT (I10)
0060        200 FORMAT (1H1,19A4)
0061        201 FORMAT (33HONTYPES OF EQUIPMENTS/COMPONENTS=,I5)
0062        301 FORMAT (/ 20X,30HCOMPONENT INTERMEDIATE RESULTS/6X,1HN,2X,
               *         9HPROB REMV,2X,
               *   8HCUMULTVE,2X,8HPROB R-1/
               *     3X,4HOR R,3X,6X,1HN,3X,10X,10HREPLACEMNT/)
0063        302 FORMAT (I10,6F10.6)
0064        303 FORMAT (I10,20X,F10.6)
0065        304 FORMAT (//10X,6HCAUSE , 4A4/)
0066            END
```

```
0001          SUBROUTINE RDCCMP
0002          IMPLICIT REAL * 4 (A-H,C-Z)
0003          REAL * 4 LA,LA4,LA4SUM
0004          COMMON T,IAU,XMAP
0005          COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
0006          COMMON WEIPA(400),WEIBP(400)
0007          COMMON XNK,XXK,XXKP
0008          COMMON ALPHA,PHO,DELTA,UNIT(5),SUMT,         CAPT,DELTT,XIT
0009          COMMON SUMBAC,SUMBAV,SUMPRE,OMEGA(2)
0010          COMMON AC,AV,RE
0011          COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100  )
0012          COMMON RKLO,SSLIFE,FFS,CAPPA2
0013          COMMON PRODBF(100),A(100,5),ASUM(100,5)
0014          COMMON HK(5),CK(9),SUMCC(14,10),CRES(14,10),CAUSE( 4,5)
0015          COMMON POLY(100),PREIL(5),PREIL2(5)
0016          COMMON PCLY1(201),PCLY2(201),PCLY3(201)
0017          COMMON B(10,10,5)
0018          COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
0019          COMMON ITLE(20),NMISS,ICPT,NTYPES,IPR,   NLIST,MLIST( 10),MSTART
0020          COMMON MISNAM(10),MISDES(20,5)
0021          COMMON I,IM1,ITYPES
0022          COMMON NCURVE,NSIZE(100),ACCPT(100),NACC(100)
0023          COMMON IBEG(100),IENAME(4),ICNAME(4)
0024          COMMON NFAILS,IVENO1(10),IVENO2(10),MODTYP(10)
0025          COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
0026          COMMON IPERB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
0027          COMMON IREAD,IWRITE,IFUNAM(4)
0028          COMMON ISYS,    NMISP1,MSPAR,MSPAP1
0029          COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
0030          COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
0031          COMMON PREL4(10), HK4(10),  B4(10,10,10),A4(100,10),ASUM4(100,10)
0032          COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
0033          COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
0034          COMMON CRPRL4(5),SUMEX(12,10),SUMEY(6,10)
0035          DIMENSION FRMU(6),FRMUNM(6)
0036          DATA FRMU/.25,.5,.75,1.,1.5,2./
0037          DATA FRMUNM/4H 1/4,4H 1/2,4H 3/4,4H    ,4H 3/2,4H  2 /
0038          IMAX3 = 200
0039          READ (5,102) (IENAME(M),M=1,4),     XNK,XXK,XXKP,MSPAR,IFUNAM
0040          IF (MSPAR .GT. IMAX3)  MSPAR = IMAX3
0041          WRITE (6,202) ITYPES,(IENAME(M),M=1,4),XNK,XXK,XXKP,MSPAR,(FUNAM
0042          IF (XNK .LT. 1.) GO TO 96
0043          MSPAP1 = MSPAR + 1
0044          READ (5,103) (ICNAME(M),M=1,4),NFAILS,PHO,IALPHA,IBETAC,IGAMM1,
             *  IGAMM2,DELTA,IPERB,(UNIT(K),K=1,5)
0045                   IPERB = NMISS + 1
0046          WRITE (6,203) ITYPES,(ICNAME(M),M=1,4),NFAILS,PHO,IALPHA,IBETAC,
             *    IGAMM1,IGAMM2,DELTA,IPERB,(UNIT(K),K=1,5)
0047          IF (DELTA .GT. 1. .OR. DELTA .LT. 0.) GO TO 95
0048          IF (IBETAC .GT. NCURVE .OR. IGAMM1 .GT. NCURVE .OR. IGAMM2 .GT.
             *   NCURVE .OR. IALPHA .GT. NCURVE)     GO TO 99
0049          IF (NFAILS .GT. 10 .OR. NFAILS .LT. 1) GO TO 94
0050          READ (5,104) (MODTYP(IFAILS),IVENO1(IFAILS),IVENO2(IFAILS),
             *  ICR(IFAILS),
             *    IFAILS=1,NFAILS)
0051          WRITE(6,204) (MODTYP(IFAILS),IVENO1(IFAILS),IVENO2(IFAILS),
```

```
              *    ICR(IFAILS),
              *     IFAILS=1,NFAILS)
0052             DO 51  IFAILS=1,NFAILS
0053             IF (MODTYP(IFAILS) .LT. 1 .OR. MODTYP(IFAILS) .GT. 2 .OR.
              *    IVENO1(IFAILS) .LT. 0 .OR. IVENO1(IFAILS) .GT. NCURVE .OR.
              *    IVENO2(IFAILS) .LT. 0 .OR. IVENO2(IFAILS) .GT. NCURVE)
              *   GO TO 97
0054          51 CONTINUE
0055             READ (5,951)            (CK(I),I=1,8),(HK(I),I=1,5)
0056             WRITE (6,952)           (CK(I),I=1,8),(HK(I),I=1,5)
0057             IF (HK(5) .EQ. 0.)  HK(5) = 1.E20
0058             READ (5,951)  (CK3(I),I=1,NFAILS)
0059             WRITE (6,953)  (CK3(I),I=1,NFAILS)
0060             READ (5,951)  (CK6(I),I=1,NFAILS)
0061             WRITE (6,953)  (CK6(I),I=1,NFAILS)
0062             READ (5,951) (HK4(I),I=1,NFAILS)
0063             WRITE (6,953)  (HK4(I),I=1,NFAILS)
0064             WRITE (18,401)
0065             WRITE (18,402) ((FNAME(K),K=1,4),(ICNAME(K),K=1,4),(FUNAM,
              *      RHO,(UNIT(K),K=1,5)
0066             WRITE (18,403) XNK,           MSPAR
0067             WRITE (18,400)
0068             WRITE (18,404) NFAILS
0069             DO 52  IFAILS=1,NFAILS
0070             IRKLC = IVENO1(IFAILS)
0071             XMU = 0.
0072             MODE = MODTYP(IFAILS)
0073             WRITE (18,452) MODE,IFAILS ,ICR(IFAILS)
0074             ISWICH = 1
0075             XMU = 0.
0076             IF (MODE .NE. 2)  ISWICH = 0
0077             DO 53  ICVE=1,MODE
0078             WRITE (18,451) ICVE,IRKLC,(CURNAM(K,IRKLC),K=1,10)
0079             NPTS = NSIZE(IRKLC)
0080             IC2 = NCOPT(IRKLC) + 1
0081             ISTORE = IBEG(IRKLC)
0082             IF (NRTS .NE. 1)  ISWICH = 0
0083             DO 2  IPTS=1,NRTS
0084             GO TO (11,12  ),IC2
0085          11 CONTINUE
0086             WRITE (18,406) IRTS,(PCNAM(K,ISTORE),K=1,10),CURVEX(ISTORE),
              *      CURVEY(ISTORE)
0087             GO TO 3
0088          12 CONTINUE
0089             WRITE (18,407)       (PCNAM(K,ISTORE),K=1,10),WEIBA(ISTORE),
              *      WEIBB(ISTORE),CURVEX(ISTORE),CURVEY(ISTORE)
0090             XMU = XMU+CURVEX(ISTORE)
0091           3 CONTINUE
0092             ISTORE = ISTORE + 1
0093           2 CONTINUE
0094             IRKLC = IVENO2(IFAILS)
0095          53 CONTINUE
0096             IF (ISWICH .EQ. 0)  GO TO 52
0097             DO 61  I=1,6
0098             TE1(I) = FRMU(I) * XMU
0099             JFAILS = IFAILS
```

```
      TE11 = COMPRK(TE10,JFAILS,JFAILS)
      WRITE (18,411) FRMLAM(I)),TE10,TE11
   61 CONTINUE
   52 CONTINUE
      NPTS = NSIZE(IBETAC)
      IC2 = NCOPT(IBETAC) + 1
      ISTORE = IBEG(IBETAC)
      WRITE (18,504)  IBETAC,(CURNAM(K,IBETAC),K=1,10)
      DO 25 IPTS=1,NPTS
      GO TO (21,22    ),IC2
   21 CONTINUE
      WRITE (18,506) IPTS,(PC(NAM(K,ISTORE),K=1,10),CURVEX(ISTORE),
     *     CURVEY(ISTORE)
      GO TO 24
   22 CONTINUE
      WRITE (18,507)        (PC(NAM(K,ISTORE),K=1,10),WEIBA(ISTORE),
     *     WEIBB(ISTORE),CURVEX(ISTORE),CURVEY(ISTORE)
   24 CONTINUE
      ISTORE = ISTORE + 1
   25 CONTINUE
      NPTS = NSIZE(IGAMM1)
      IC2 = NCOPT(IGAMM1) + 1
      ISTORE = IBEG(IGAMM1)
      WRITE (18,634)  IGAMM1,(CURNAM(K,IGAMM1),K=1,10)
      DO 45 IPTS=1,NPTS
      GO TO (41,42    ),IC2
   41 CONTINUE
      WRITE (18,606) IPTS,(PC(NAM(K,ISTORE),K=1,10),CURVEX(ISTORE),
     *     CURVEY(ISTORE)
      GO TO 44
   42 CONTINUE
      WRITE (18,607)        (PC(NAM(K,ISTORE),K=1,10),WEIBA(ISTORE),
     *     WEIBB(ISTORE),CURVEX(ISTORE),CURVEY(ISTORE)
   44 CONTINUE
      ISTORE = ISTORE + 1
   45 CONTINUE
      GAMMA2 = CURVE(IGAMM2,TAU,1)
      WRITE (18,614) GAMMA2,IGAMM2,(CURNAM(K,IGAMM2),K=1,10)
      DELTAP = 1.-DELTA
      WRITE (18,704) DELTAP
      ALPHA = CURVE (IALPHA,TAU,1)
      WRITE (18,804)  ALPHA,IALPHA,(CURNAM(K,IALPHA),K=1,10)
      IF (IRERB .LE. NMISS)  WRITE (18,901)  IRERB
      WRITE (18,850)
      WRITE (18,851) (CK(I),I=1,8),(HK(I),I=1,5)
      WRITE (18,852) (CK3(IFAILS),IFAILS=1,NFAILS)
      WRITE (18,853) (CK6(IFAILS),IFAILS=1,NFAILS)
      WRITE (18,854) (HK4(IFAILS),IFAILS=1,NFAILS)
      RETURN
   99 WRITE (6,301) IBETAC,IGAMM1,IGAMM2,IALPHA,NCURVE
      STOP
   98 WRITE (6,302) NFAILS
      STOP
   97 WRITE (6,303) JFAILS
      STOP
   96 WRITE (6,304)
```

```
0152            STOP
0153         95 WRITE (6,305)
0154            STOP
0155        102 FORMAT (4A4,4X,3F10.0,I10,7X,2A4,A3,A2)
0156        202 FORMAT (6H0EQUIP,I5,3X,4A4,5X,5H XKK=,F10.0,
             1     5X,4HXXK=,F10.0,5X,5HXXKP=,F10.0,5X,6HMSPAR=,I5,
             *     2X,7HIFUNAM=,2A4,A3,1X,A2)
0157        103 FORMAT (4A4,4X,I5,F5.0,4I5,F5.0,I5,5A4)
0158        104 FORMAT (10(I1,I2,I2,I1))
0159        204 FORMAT (11H FAIL MODES,10(I3,I3,I3,I3))
0160        203 FORMAT (5H COMP,I5,1X,4A4,2X,7HNFAILS=,I3,2X,4HRHO=,F7.4/29X,
             *     7HIALPHA=,I3,2X,7HIBETAC=,I3,2X,7HIGAMM1=,I3,2X,7HIGAMM2=,
             *     I3,2X,6HDELTA=, F7.4,2X,6HIRFRB=,I5,
             *              2X,5HUNIT=,5A4)
0161        400 FORMAT (1H0,35X,10(1H*),30HCOMPONENT LIFE CHARACTERISTICS,10(1H*))
0162        401 FORMAT (1H1,35X,10(1H*),
             *                    32HCOMPONENT/EQUIPMENT REQUIREMENTS,10(1H*)//)
0163        402 FORMAT (16H EQUIPMENT NAME ,4A4,2X,15HCOMPONENT NAME ,4A4,2X,
             *   13HFUNCTION CODE,1X,2A4,A3,1X,A2/30X,
             *   9HUTIL RATE,F7.4,2X,17H FAILURE ARGUMNT , 5A4 )
0164        403 FORMAT (1H0,4X,33HNUMBER OF COMPONENTS IN EQUIPMENT,22X,F10.0/
             1     1H0,4X,14HMAXIMUM SPARES,41X,I10/)
0165        404 FORMAT (
             1     1H0,4X,23HNUMBER OF FAILURE MODES,I10/)
0166        406 FORMAT (9X,5HPOINT,
             *              I5,2X,1X,10A4,1X, 6HLINEAR      ,3X,4HIND=,F10.2,
             1     5X,5HPROB=,F7.4)
0167        407 FORMAT (        17X,2X,10A4,1X, 6HWEIBUL      ,3X,2HA=,F14.6,1X,
             *     2HB=,F7.4,2X,3HMU=,F10.2,1X,8HP(MU/2)=,F7.4)
0168        411 FORMAT (80X,A4,4H MU=,F20.4,5X,2HP=,F10.5)
0169        451 FORMAT (6H STAGE,I5,5X,15HUSES CURVE NO. ,I5,10X,10A4)
0170        452 FORMAT (26H NUMBER OF FAILURE STAGES=,I5,9H FOR MODE,I5,
             *       5X,12HCRITICALITY=,I5)
0171        504 FORMAT (1H0,30X,10(1H*),37HMAINTENANCE FREQUENCY CHARACTERISTICS,
             *     10(1H*)/  1H0,4X,
             *    65HPROBABILITY OF NO PREVENTIVE MAINTENANCE WITH COMPONENT USE(B
             *ETA)/60X,16H USES CURVE NO. ,I5,1X,10A4)
0172        506 FORMAT (9X,5HPOINT,
             *              I5,2X,1X,10A4,1X, 6HLINEAR      ,3X,4HIND=,F10.2,
             1     5X,5HPROB=,F7.4)
0173        507 FORMAT (        17X,2X,10A4,1X, 6HWEIBUL      ,3X,2HA=,E14.6,1X,
             *     2HB=,F7.4,2X,3HMU=,F10.2,1X,8HP(MU/2)=,F7.4)
0174        604 FORMAT (1H0,4X,75HPROBABILITY OF INITIATING PREVENTIVE MAINTENANCE
             * WITH COMPONENT USE(GAMMA1)/
             *     60X,15HUSES CURVE NO. ,I5,1X,10A4)
0175        606 FORMAT (9X,5HPOINT,
             *              I5,2X,1X,10A4,1X, 6HLINEAR      ,3X,4HIND=,F10.2,
             1     5X,5HPROB=,F7.4)
0176        607 FORMAT (        17X,2X,10A4,1X, 6HWEIBUL      ,3X,2HA=,E14.6,1X,
             *     2HB=,F7.4,2X,3HMU=,F10.2,1X,8HP(MU/2)=,F7.4)
0177        614 FORMAT (1H0,4X,57HPROBABILITY OF COMPLETING PREVENTIVE MAINTENANCE
             *(GAMMA2)=, F10.6/60X,
             *                  16H USES CURVE NO. ,I5,1X,10A4)
0178        704 FORMAT (1H0,4X,56HPROBABILITY OF HANDLING/TRANSPORTATION FAILURE(I
             *-DELTA)=,F10.6/)
0179        804 FORMAT (1H0,4X,82HPROBABILITY OF COMPLETING CORRECTIVE MAINTENANCE
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                   * FCLLCWING MISSION FAILUPE(ALPHA)=,F10.6/
                   *    60X,15HUSES CURVE NO. ,I5,1X,10A4)
0180           901 FORMAT (1H0,4X,27HCCMPCNENT REBUILCING CYCLE=,I5,
                   *       10H (MISSION))
0181           301 FORMAT (45H0(BETA0 OR (GAMM1 OR (GAMM2 OR (ALPHA TCO BIG,5I10)
0182           302 FORMAT (24H0NFAILS TCC BIG CR SMALL,I10/)
0183           303 FORMAT (20H0BAD DATA FCR FAILS=,I10/)
0184           304 FORMAT ( 8H0XNK BAD/)
0185           305 FORMAT (10H0DELTA BAD/)
0186           850 FORMAT (1H0,30X,10(1H*),19HCOST AND HOURS DATA,10(1H*)/)
0187           851 FORMAT (
                   *    40H COST PER SERVICE MAN HOUR               ,10X,F10.2/
                   *    40H COST PER PM MAN HOUR                    ,10X,F10.2/
                   *    40H COST PER CM MAN HOUR FOR H/T            ,10X,F10.2/
                   *    40H MATERIAL COST PER SERVICE               ,10X,F10.2/
                   *    40H MATERIAL COST PER PM                    ,10X,F10.2/
                   *    40H MATERIAL COST PER CM FOR H/T            ,10X,F10.2/
                   *    40H COST UNAVAILABLE                        ,10X,F10.2/
                   *    40H COST UNRELIABLE                         ,10X,F10.2/
                   *    40H MAN HOURS PER SERVICE                   ,10X,F10.2/
                   *    40H MAN HOURS PER PM                        ,10X,F10.2/
                   *    40H MAN HOURS PER H/T FAILURE               ,10X,F10.2/
                   *    40H MAN HOURS PER MISSION FAILURE(NOT USED) ,10X,F10.2/
                   *    40H OPERATING INTERVAL PER SERVICE ACTION   ,10X,F10.2/)
0188           852 FORMAT (30H COST PER CM MAN HOUR BY MODE ,10F10.3)
0189           853 FORMAT (30H MATERIAL COST PER CM BY MODE ,10F10.3)
0190           854 FORMAT (30H MAN HOURS MISS FAIL BY MODE  ,10F10.3)
0191           951 FORMAT (13F6.0)
0192           952 FORMAT (7HCOSTS=,8F8.2,4X,6HHOURS=,5F8.2)
0193           953 FORMAT (5X,10F8.2)
0194               END
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0001          SUBROUTINE INIT2
         C        INITIALIZE EQUIPMENT TOTALS   OVER ALL MISSIONS
         C                  AND PRECOMPUTE CURVE DATA
0002          IMPLICIT REAL * 4 (A-H,O-Z)
0003          REAL * 4 LA,LA4,LA4SUM
0004          COMMON T,TAU,XMAR
0005          COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
0006          COMMON WEIBA(400),WEIBB(400)
0007          COMMON XNK,XXK,XXKP
0008          COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
0009          COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
0010          COMMON AC,AV,RE
0011          COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100  )
0012          COMMON RKLO,SSLIFE,EPS,GAMMA2
0013          COMMON PRODBE(100),A(100,5),ASUM(100,5)
0014          COMMON HK(5),CK(9),SUMCO(14,10),CRES(14,10),CAUSE( 4,5)
0015          COMMON POLY(100),PRFIL(5),PRFIL2(5)
0016          COMMON POLY1(201),POLY2(201),POLY3(201)
0017          COMMON B(101,10,5)
0018          COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
0019          COMMON ITLF(20),NMISS,ICPT,NTYPES,IPR,   NLIST,MLIST( 10),MSTART
0020          COMMON MISNAM(10),MISDES(20,5)
0021          COMMON I,IM1,ITYPES
0022          COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
0023          COMMON IBEG(100),IENAME(4),ICNAME(4)
0024          COMMON NFAILS,IVENC1(10),IVENO2(10),MODTYP(10)
0025          COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
0026          COMMON IRFRB,ICYC,ICYCM1,JCEL1,JMAX,JCEL2
0027          COMMON IREAD,IWRITE,IFUNAM(4)
0028          COMMON ISYS,    NMISP1,MSPAP,MSPAP1
0029          COMMON NPOLY1,NPOLY2,NPOLY3,CPESHT(3,10),SUMCHT(3,10)
0030          COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
0031          COMMON RREL4(10), HK4(10),  B4(101,10,10),A4(100,10),ASUM4(100,10)
0032          COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
0033          COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
0034          COMMON CRPPL4(5),SUMEX(12,10),SUMEY(6,10)
0035          MSTART = 1
0036          RHOT = RHO * T
0037          TE1 = 0.
0038          WRITE (18,803)
0039          TE3P = 1.
0040          ISWTE3 = 0
0041          DO 2  I=1,NMISS
0042          IF (I .GT. IRFRB)  GO TO 11
0043          TE1 = TE1 + RHOT
0044          TE3 = 0.
0045          DO 61  IFAILS=1,NFAILS
0046          IF (TE3P .LT. EPS .AND. I .NE. 1 .AND. ISWTE3 .EQ. 1) GO TO 62
0047          RKLINT(I,IFAILS)=COMPIN(TE1-RHOT,TE1,IFAILS)
0048          TE3 = TE3 + RKLINT(I,IFAILS)
0049          IF (TE3 .GT. EPS)  ISWTE3 = 1
0050          GO TO 61
0051       62 RKLINT(I,IFAILS) = 0.
0052       61 CONTINUE
0053          TE3P = TE3
0054          IF (I .NE. I .AND. RKL(I-1) .LT.   EPS)  GO TO 5
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      RKL(I) = COMPRK(TE1,I,NFAILS)
      GO TO 6
    5 RKL(I) = 0.
    6 CONTINUE
      GAMMA(I) = ICURVE(IGAMM1,TE1,1))
      BETA(I) = CURVE(IBETAC,TE1,0)
      IF (GAMMA(I)+BETA(I) .GT. 1.)  GO TO 99
      GAMMA(I) = GAMMA(I) * GAMMA2
      TE2 = 1.-BETA(I)-GAMMA(I)
      IF (RKL(I) .NE. 0.)  WRITE (18,804) I,TE1,RKL(I),BETA(I),
     *      GAMMA(I),TE2,(RKLINT(I,IFAILS),IFAILS=1,NFAILS)
    2 CONTINUE
   11 CONTINUE
      RKLO = COMPRK(0.,1,NFAILS)
      PROD = 1.
      PA = 1.
      PAC = 1.
      AC = 1.    - ALPHA
      PD = 1.
      DO 1 I=1,NMISS
      IF (I .GT. IRFRB)  GO TO 12
      PROD = PROD * BETA(I)
      IF (PROD .LT. 1.E - 20)  PROD = 0.
      PRODBE(I) = PROD
      PA = PA * ALPHA
      IF (PA .LT. 1.E - 20)  PA = 0.
      ALPHAL(I) = PA
      PAC = PAC * AC
      IF (PAC .LT. 1.E - 20)  PAC = 0.
      ALPHAC(I) = PAC
      PD = PD * DELTA
      IF (PD .LT. 1.E - 20)  PD = 0.
      DELTAL (I) = PD
      IF (IPR .NE. 0)  WRITE (16,401) I,
     1                  PRODBE(I),ALPHAL(I),ALFHAC(I),DELTAL(I)
    1 CONTINUE
   12 CONTINUE
      RETURN
   99 WRITE (6,301) I,GAMMA(I),BETA(I)
      STOP
  301 FORMAT (30HOGAMMAI+BETA GREATER THAN ONE ,I5,2F16.8)
  401 FORMAT (6H INIT2,I5,8G12.4)
  803 FORMAT (1HO,29X,4X,22HPREVENTIVE MAINTENANCE/
     *          3X,7HMISSION,5X,5HUSAGE,2X,8HSURVIVAL,3X,7HNONE     ,
     *          2X,8HCOMPLETE,1X,10HINCOMPLETE,1X,14HMODE INTEGRALS/)
  804 FORMAT (I10,F10.2,4F10.6,10F7.4)
      END
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      SUBROUTINE COMP1
C         COMPUTE A
      IMPLICIT REAL * 4 (A-H,O-Z)
      REAL * 4 LA,LA4,LA4SUM
      COMMON T,TAU,XMAP
      COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIPE(400)
      COMMON XNK,XXK,XXKP
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SLMBPE,OMEGA(2)
      COMMON AC,AV,PE
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100  )
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON PROCPE(100),A(100,5),ASUM(100,5)
      COMMON HK(5),CK(9),SUMCC(14,10),CRES(14,10),CAUSE( 4,5)
      COMMON POLY(100),PREIL(5),PREIL2(5)
      COMMON POLY1(201),POLY2(201),POLY3(201)
      COMMON B(101,10,5)
      COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
      COMMON ITLE(20),NMISS,ICPT1,NTYPES,IPR,   NLIST,MLIST( 10),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),IGNAME(4)
      COMMON NFAILS,IVEND1(10),IVEND2(10),MODTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IRFRB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      COMMON ISYS,    NMISP1,MSPAR,MSPAP1
      COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
      COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
      COMMON PREL4(10), RK4(10),  B4(101,10,10),A4(100,10),ASUM4(100,10)
      COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
      COMMON NCRIT,ICR(10),CRCR47(10,5),CRCP48(10,5),CRCR49(10,5)
      COMMON CRPRL4(5),SUMEX(12,10),SUMEY(6,10)
      I = 1
      IU = 0
      TE1 = RKL(I)
      TE2 = TE1 * DELTA
      TE3 = (1.    - TE2)
      TE4 = TE3 * ALPHA
      TE5 = GAMMA(I)
      A(1,5)=TE2 * TE5 + TE4
      SUMA = A(I,5)
      IF ((PR .NE. 0) WRITE (16,301) ),IU,TE1,TE2,TE3,TE4,TE5,A(I,5)
      IF (NMISS .EQ. 1)  GO TO 2
      DO 3  I=2,NMISS
    3 A(I,5)=0.
      DO 1 I=2,NMISS
      IF (I .GT. IRFRB)  GO TO 2
      IM1 = I-1
      TE11 = DELTAL(I)
      TE12 = RKL(I)
      TE13 = PROCPE(IM1)
      TE14 = GAMMA(I)
      TE27 = ALPHAC(IM1)
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0056         TE20 = TE11*TE12*TE13*TE14+TE4 *TE27
0057         SUM1 = 0.
0058         DO 31 IU=1,IM1
0059         IUM1 = IU - 1
0060         IMIUM1 = I - IU - 1
0061         IF (IUM1) 11,11,12
0062      11 TE30 = 1.
0063         GO TO 13
0064      12 TE30 = PRODRE(IUM1)
0065      13 CONTINUE
0066         IF (IMIUM1)  32,32,33
0067      32 TE17 = 1.
0068         GO TO 34
0069      33 TE17 = ALPHAC(IMIUM1)
0070      34 CONTINUE
0071         TE21 = DELTAL(IU)
0072         TE18 = RKL(IU+1)
0073         TE31 = (TE21*TE17) * ALPHA*TE30
0074         TE32 = (1.  -GAMMA(IU I) * RKL(IU )
0075         TE33 = BETA(IU I * TE18 * DELTA
0076         TE34 = TE31 * (TE32-TE33)
0077         SUM1 = SUM1 + TE34
0078         IF (IPR .NE. 0) WRITE(6,301) I,IU,TE1,TE2,TE3,TE4,TE5,
           1  TE11,TE12,TE13,TE14,      TE17,TE18,TE20,TE21,TE27,TE30,
           3   TE31,TE32,TE33,TE34,SUM1,A(I,5),SUMA
0079      31 CONTINUE
0080         A(I,5)=TE20 + SUM1
0081      24 CONTINUE
0082         SUMA = SUMA + A(I,5)
0083         IF (ABS(SUMA-1.) .LT. EPS)  GO TO 2
0084       1 CONTINUE
0085       2 CONTINUE
0086         IF (IRFRB .GT. NMISS)  GO TO 25
0087         A(IRFRB,5)=A(IRFRB,5)+1.-SUMA
0088      25 CONTINUE
0089         DO 51  J=1,4
0090         DO 51  N=1,NMISS
0091      51 A(N,J) = 0.
0092         DO 61   IFAILS=1,NFAILS
0093         DO 61   N=1,NMISS
0094      61 A4(N,IFAILS) = 0.
0095         N = 1
0096         DO 52   J=1,4
0097      52 A(N,J) = LA(N,J)
0098         DO 62   IFAILS=1,NFAILS
0099      62 A4(N,IFAILS) = LA4(N,IFAILS)
0100         IF (IPR .NE. 0)  WRITE (6,301) N,N,(A(N,J),J=1,5)
           *       ,(A4(N,IFAILS),IFAILS=1,NFAILS)
0101         IF (NMISS .EQ. 1)  GO TO 56
0102         DO 55  N=2,NMISS
0103         NM1 = N - 1
0104         DO 53   J=1,4
0105         DO 54   I=1,NM1
0106         NMI = N - I
0107      54 A(N,J) = A(N,J)+(LA(I,5)-LA(I,J))*A(NMI,J)
0108      53 A(N,J)=A(N,J)+LA(N,J)
```

```
 0109              DO 63  IFAILS=1,NFAILS
 0110              DO 64  I=1,NMI
 0111              NMI = N - I
 0112           64 A4(N,IFAILS)=A4(N,IFAILS)+(LA(I,5)-LA4(I,IFAILS))*A4(NMI,IFAILS)
 0113           63 A4(N,IFAILS) = A4(N,IFAILS)+LA4(N,IFAILS)
 0114              IF (IPR .NE. 0) WRITE (16,301) N,N,(A(N,J),J=1,5)
                *      ,IA4(N,IFAILS),IFAILS=1,NFAILS)
 0115           55 CONTINUE
 0116           56 CONTINUE
 0117              RETURN
 0118          301 FORMAT (6H COMP1,2I5,5G20.8/I16X,5G20.8))
 0119              END
```

```
      SUBROUTINE COMP2
C                    COMPUTE THE SUMS OF A'S
      IMPLICIT REAL * 4 (A-H,O-Z)
      REAL * 4 LA,LA4,LA4SUM
      COMMON T,TAU,XMAR
      COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,10)
      COMMON WEIBA(400),WEIBP(400)
      COMMON XNK,XXK,XXKF
      COMMON ALPHA,RHO,DELTA,LNIT(5),SUMT,           CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
      COMMON AC,AV,RE
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100  )
      COMMON RKLO,SSLIFF,EPS,GAMMA2
      COMMON PRODBE(100),A(100,5),ASUM(100,5)
      COMMON HK(5),CK(9),SUMC(14,10),CRES(14,10),CAUSE( 4,5)
      COMMON POLY(100),PPFIL(5),PPFIL2(5)
      COMMON POLY1(201),PCLY2(201),PCLY3(201)
      COMMON B(101,10,5)
      COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
      COMMON ITLE(20),NMISS,ICFT1,NTYPES,IPR,   NLIST,MLIST( 10),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IMI,ITYPES
      COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),ICNAME(4)
      COMMON NFAILS,IVENC1(10),IVENC2(10),MCOTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IREPR,ICYC,ICYCM1,JCEL1,JMAX1,JCEL2
      COMMON IREAD,IWRITE,IFLNAM(4)
      COMMON ISYS,    NMISPI,MSPAR,MSPAPI
      COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
      COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
      COMMON PRFL4(10), HK4(10),  B4(101,10,10),A4(100,10),ASUM4(100,10)
      COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
      COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
      COMMON CRPRL4(5),SUMEX(12,10),SUMEY(6,10)
      DO 1  J=1,5
      DO 2  N=1,NMISS
    2 ASUM(N,J) = 0.
      SUMJ = 0.
      DO 3  N=1,NMISS
      SUMJ = SUMJ + A(N,J)
      ASUM(N,J) = SUMJ
    3 CONTINUE
    1 CONTINUE
      DO 11  IFAILS=1,NFAILS
      DO 12  N=1,NMISS
   12 ASUM4(N,IFAILS) = 0.
      SUMJ = 0.
      DO 13  N=1,NMISS
      SUMJ = SUMJ  +  A4(N,IFAILS)
      ASUM4(N,IFAILS) = SUMJ
   13 CONTINUE
   11 CONTINUE
      RETURN
      END
```

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```
      SUBROUTINE COMP3
C           COMPUTE FOR ALL CAUSES AND TOTAL
      IMPLICIT REAL * 4 (A-H,O-Z)
      REAL * 4 LA,LA4,LA4SUM
      COMMON T,TAU,XMAP
      COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIPB(400)
      COMMON XNK,XXK,XXKP
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
      COMMON AC,AV,RF
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100  )
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON PRODBE(100),A(100,5),ASUM(100,5)
      COMMON HK(5),CK(9),SUMCO(14,10),CRES(14,10),CAUSE( 4,5)
      COMMON PCLY(100),PRFIL(5),PRFIL2(5)
      COMMON POLY1(20),POLY2(20),POLY3(20)
      COMMON P(10,10,5)
      COMMON ALPHA(100),ALPHAC(100),DELTAL(100)
      COMMON ITLE(20),NMISS,ICPT1,NTYPES,IPR,   NLIST,MLIST( 10),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),ACCPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),IGNAME(4)
      COMMON NFAILS,IVENO1(10),IVENO2(10),MODTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IRFRB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      COMMON ISYS,    NMISP1,MSPAR,MSPAP1
      COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
      COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
      COMMON PREL4(10), HK4(10),   B4(10,10,10),A4(100,10),ASUM4(100,10)
      COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
      COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
      COMMON CRPRL4(5),SUMEX(12,10),SUMEY(6,10)
      DO 51  J=1,5
      DO 2 IR=1,NMISS
    2 POLY(IR) = A(IR,J)
      DO 1 M=1,NLIST
      INU = MLIST(M)
      B(1,M,J) = 1.-ASUM(INU,J)
    1 CONTINUE
      DO 3 IR=1,NMISS
      IRP1 = IR + 1
      DO 4 M=1,NLIST
      INU = MLIST(M)
      IF (IR .GT. INU)  GO TO 4
      B(IRP1,M,J) = 0.
      DO 5 IM=IR,INU
      INUMIM = INU - IM
      IF (INUMIM.NE.0) GO TO 8
      B(IRP1,M,J)=B(IRP1,M,J)+POLY(IM)
      GO TO 5
    8 B(IRP1,M,J)=B(IRP1,M,J)+POLY(IM)*(1.-ASUM(INUMIM,J))
    5 CONTINUE
    4 CONTINUE
```

```
      IF (IR .EQ. NMISS)  GO TO  6
      CALL PMULT(POLY,A(I,J),NMISS,IRP1)
    3 CONTINUE
    6 CONTINUE
   51 CONTINUE
      DO 61  IFAILS=1,NFAILS
      DO 12  IR=1,NMISS
   12 POLY(IR) = A4(IP,IFAILS)
      DO 11  M=1,NLIST
      INU = MLIST(M)
      B4(1,M,IFAILS) = 1.-ASUM4(INU,IFAILS)
   11 CONTINUE
      DO 13  IR=1,NMISS
      IRP1 = IR + 1
      DO 14  M=1,NLIST
      INU = MLIST(M)
      IF (IR .GT. INU)  GO TO 14
      B4(IRP1,M,IFAILS) = 0.
      DO 15  IM=IP,INU
      INUMIM = INU - IM
      IF (INUMIM .NE. 0)  GO TO 18
      B4(IRP1,M,IFAILS) = B4(IRP1,M,IFAILS) + POLY(IM)
      GO TO 15
   18 B4(IRP1,M,IFAILS) = B4(IRP1,M,IFAILS) + POLY(IM) *
     *      (1.-ASUM4(INUMIM,IFAILS))
   15 CONTINUE
   14 CONTINUE
      IF (IR .EQ. NMISS)  GO TO 16
      CALL PMULT(POLY,A4(1,IFAILS),NMISS,IRP1)
   13 CONTINUE
   16 CONTINUE
   61 CONTINUE
      RETURN
      END
```

```
0001          SUBROUTINE COMP4
        C            COMPUTE LITTLE A'S  1-5
0002          IMPLICIT REAL * 4 (A-H,O-Z)
0003          REAL * 4 LA,LA4,LA4SUM
0004          COMMON T,TAU,XMAR
0005          COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
0006          COMMON WEIBA(400),WEIBP(400)
0007          COMMON XNK,XXK,XXKP
0008          COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,           CAPT,DELTT,XIT
0009          COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
0010          COMMON AC,AV,RE
0011          COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100   )
0012          COMMON PKLO,SSLIFE,EPS,GAMMA2
0013          COMMON PROBBE(100),A(100,5),ASUM(100,5)
0014          COMMON HK(5),CK(9),SUMCC(14,10),CRES(14,10),CAUSE( 4,5)
0015          COMMON POLY(100),PRFIL(5),PRFIL2(5)
0016          COMMON POLY1(201),POLY2(201),POLY3(201)
0017          COMMON B(101,10,5)
0018          COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
0019          COMMON ITLE(20),NMISS,IOPT1,NTYPES,IPP,   NLIST,MLIST( 10),MSTAPT
0020          COMMON MISNAM(10),MISDES(20,5)
0021          COMMON I,IM1,ITYPES
0022          COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
0023          COMMON IBEG(100),IFNAME(4),ICNAME(4)
0024          COMMON NFAILS,IVENO1(10),IVENO2(10),MODTYP(10)
0025          COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
0026          COMMON IPFPB,ICYC,ICYCMI,JDEL1,JMAX1,JDEL2
0027          COMMON IREAD,IWRITE,IFUNAM(4)
0028          COMMON ISYS,    NMISP1,MSPAP,MSPAP1
0029          COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
0030          COMMON LA(100,5),LA4(100,10),LA4SUM(100),PKLINT(100,10)
0031          COMMON PRFL4(10), HK4(10),   B4(101,10,10),A4(100,10),ASUM4(100,10)
0032          COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
0033          COMMON NCRIT,ICR(10),CPCP47(10,5),CRCP48(10,5),CPCR49(10,5)
0034          COMMON CRPRL4(5),SLMEX(12,10),SUMEY(6,10)
0035          DO 62  N=1,NMISS
0036       62 LA4SUM(N) = 0.
0037          N = 1
0038          LA(N,1) = DELTA*RKL(N)*GAMMA(N)
0039          LA(N,2)=RKLO*(1.-DELTA)*ALPHA
0040          LA(N,3)=0.
0041          LA(N,4)=DELTA*(RKLO-PKL(N))*ALPHA
0042          DO 61  IFAILS=1,NFAILS
0043          TE1 = PKLINT(N,IFAILS)
0044          LA4(N,IFAILS) = DELTA * TE1 * ALPHA
0045          LA4SUM(N) = LA4SUM(N) + LA4(N,IFAILS)
0046       61 CONTINUE
0047          IF (ABS(LA4SUM(N)-LA(N,4)) .GT. EPS)  WRITE (6,302) N,LA4SUM(N),
             *     LA(N,4),(LA4(N,IFAILS),IFAILS=1,NFAILS)
0048          LA(N,5)=0.
0049          DO 51  J=1,4
0050       51 LA(N,5)=LA(N,5)+LA(N,J)
0051          SUMLA = LA(N,5)
0052          IF (IPR .NE. 0)  WRITE (6,301)   N,(LA(N,J),J=1,5)
             *  , (LA4(N,IFAILS),IFAILS=1,NFAILS),LA4SUM(N)
0053          IF (NMISS .EQ. 1)  GO TO 2
```

```
      DO 4  J=1,5
      DO 4  N=2,NMISS
    4 LA(N,J) = 0.
      DO 64  N=2,NMISS
      DO 64  IFAILS=1,NFAILS
   64 LA4(N,IFAILS) = 0.
      DO 1  N=2,NMISS
      NM1 = N - 1
      LA (N,1) =DELTAL(N)*RKL(N)*PRCDBF(NM1)*GAMMA(N)
      DO 3 I =1,N
      NMI = N - I
      ALPHC = 1.
      IF (N-I .GT. 0)  ALPHC= ALPHAC(NMI)
      IF (I .GT. 1)  GO TO 52
      LA(N,2) = LA(N,2)+RKLO*ALPHC
      LA(N,4)=LA(N,4)+DELTA*(RKLC-RKL(I))*ALPHC
      DO 63  IFAILS = 1,NFAILS
      TE1 = RKLINT(1,IFAILS)
      LA4(N,IFAILS) = LA4(N,IFAILS) + CELTA * TE1 * ALPHC
   63 CONTINUE
      GO TO 53
   52 IM1 = I - 1
      LA(N,2) = LA(N,2)+DELTAL(IM1)*RKL(IM1)*PRODBE(IM1)*ALPHC
      PRCDB = 1.
      IF (I-2 .GT. 0)  PRODB=PRCDBE(I-2)
      LA(N,3) = LA(N,3)+CELTAL(IM1)*RKL(IM1)*PRODB *(1.-BETA(IM1)-
     *   GAMMA(IM1)) * ALPHC
      LA(N,4)=LA(N,4)+DELTAL(I)*(RKL(IM1)-RKL(I))*PRODBE(IM1)*ALPHC
      DO 65  IFAILS=1,NFAILS
      TE1 = RKLINT(I,IFAILS)
      LA4(N,IFAILS) = LA4(N,IFAILS) + CELTAL(I) * TE1 * PRODBE(IM1) *
     *    ALPHC
   65 CONTINUE
   53 CONTINUE
    3 CONTINUE
      LA(N,2) = LA(N,2)*(1.-CELTA)*ALPHA
      LA(N,3) = LA(N,3) * ALPHA
      LA(N,4) = LA(N,4)*ALPHA
      DO 66  IFAILS=1,NFAILS
      LA4(N,IFAILS) = LA4(N,IFAILS) * ALPHA
      LA4SUM(N) = LA4SUM(N) + LA4(N,IFAILS)
   66 CONTINUE
      DO 54  J=1,4
   54 LA(N,5) = LA(N,5) + LA(N,J)
      SUMLA = SUMLA+LA(N,5)
      IF (IPR .NE. 0)  WRITE ((6,301) N,(LA(N,J),J=1,5),
     *   (LA4(N,IFAILS),IFAILS=1,NFAILS),LA4SUM(N)
      IF (ABS(SUMLA-1.).LT. EPS)  GO TO 2
      IF (ABS(LA4SUM(N)-LA(N,4)) .GT. EPS)  WRITE (6,302) N,LA4SUM(N),
     *   LA(N,4),(LA4(N,IFAILS),IFAILS=1,NFAILS)
      IF (N .NE. IRERR)  GO TO 1
      LA(N,1) = LA(N,1) + (1.-SUMLA)
      GO TO 2
    1 CONTINUE
    2 CONTINUE
      RETURN
```

```
0106        301 FORMAT (6H COMP4,I5,5G20.8/(11X,5G20.8))
0107        302 FORMAT (8HOLA4DIFF,I5,5G20.5/(20X,5G20.8))
0108            END
```

```
      SUBROUTINE COMPS
C        COMPUTE E  EP  EPP
      IMPLICIT REAL * 4 (A-H,O-Z)
      REAL * 4 LA,LA4,LA4SUM
      COMMON T,TAU,XMAP
      COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON XNK,XXK,XXKF
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBPE,OMEGA(2)
      COMMON AC,AV,RF
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100  )
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON RRODRF(100),A(100,5),ASLM(100,5)
      COMMON HK(5),CK(9),SUMCC(14,10),CRES(14,10),CAUSE( 4,5)
      COMMON POLY(100),PRFIL(5),PRFIL2(5)
      COMMON POLY1(201),POLY2(201),POLY3(201)
      COMMON B(101,10,5)
      COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
      COMMON ITLE(20),NMISS,ICFT1,NTYPES,IPR,   NLIST,MLIST( 10),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),ICNAME(4)
      COMMON NFAILS,IVENC1(10),IVENC2(10),MCCTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IREPB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      COMMON ISYS,    NMISP1,MSPAR,MSPAR1
      COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
      COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
      COMMON PPEL4(10), HK4(10),  B4(101,10,10),A4(100,10),ASUM4(100,10)
      COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
      COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
      COMMON CRPRL4(5),SUMEX(12,10),SUMEY(6,10)
      DATA MCDENM/4HMCDE/
      DATA CCDENM/4HCODE/
      NK = XNK
      WRITE (18,101) ((ITLE(M),M=1,19) ,(IENAME(I),I=1,4),IFUNAM,NK
      WRITE (18,401)
      WRITE (19,101) ((ITLE(M),M=1,19) ,(IENAME(I),I=1,4),IFUNAM,NK
      WRITE (19,701) (MCDENM,(IFAILS=1,NFAILS)
      WRITE (19,704) (IFAILS,(IFAILS=1,NFAILS)
      WRITE (21,101) ((ITLE(M),M=1,19) ,(IENAME(I),I=1,4),IFUNAM,NK
      WRITE (21,708) (CCDENM,ICRIT=1,NCRIT)
      WRITE (21,709) ((CRIT,(ICRIT=1,NCRIT)
      SYS = ISYS
      USAGE = 0.
      DO 9 M=1,NLIST
      INU = MLIST(M)
      DO 51  J=1,5
      SUM1 = 0.
      SUM2 = 0.
      XR = 0.
      DO 2 IR=1,INU
      IS=IR+1
```

```
      XR = XR + 1.
      SUMI = SUMI + XR * R(IS,M,J)
      SUM2 = SUM2+XR*XR*R(IS,M,J)
    2 CONTINUE
      PRFIL(J ) = SUMI
      TEI = SUM2-SUMI*SUMI
      IF (TEI .GT. 0.) GO TO 54
      IF (-TEI .GT. EPS) WRITE (6,501) M,J,TEI
      TEI = 0.
   54 CONTINUE
      PRFIL2(J) = SQRT(TEI)
   51 CONTINUE
      DO 61 IFAILS=1,NFAILS
      SUMI = 0.
      XR = 0.
      DO 12 IR=1,INU
      IS=IR+1
      XR = XR + 1.
      SUMI = SUMI + XR * R4(IS,M,IFAILS)
   12 CONTINUE
      PRFL4(IFAILS) = SUMI
   61 CONTINUE
      USAGE = (NU + T
      E0 = USAGE/HK(5)
      E5 = ALPHA*(PRFIL(2)+PRFIL(4))
      E6 = (1.-ALPHA)*(PRFIL(2)+PRFIL(4))
      E7 = PRFIL(3)+E6
      E8 = PRFIL(1) + E5
      DO 81 J=1,5
      PRFIL(J) = PRFIL(J) * XNK
   81 CONTINUE
      E0 = E0 * XNK
      E5 = E5 * XNK
      E6 = E6 * XNK
      E7 = E7 * XNK
      E8 = E8 * XNK
      DO 72 ICRIT=1,NCRIT
   72 CRPRL4(ICRIT) = 0.
      DO 82 IFAILS=1,NFAILS
      PRFL4(IFAILS) = PRFL4(IFAILS) * XNK
      ICRIT = ICR(IFAILS)
      CRPRL4(ICRIT) = CRPRL4(ICRIT) + PRFL4(IFAILS)
   82 CONTINUE
      WRITE (18,402) MLIST(M),E0,PRFIL(1),PRFIL(3),E5,E6,PRFIL(2),
     *     PRFIL(4),E8,E7,PRFIL(5)
      WRITE (19,602) MLIST(M),PRFIL(2),(PRFL4(IFAILS),IFAILS=1,NFAILS)
      WRITE (21,710) MLIST(M),PRFIL(4),(CRPRL4(ICRIT),ICRIT=1,NCRIT)
      SUMEX(1,M) = SUMEX(1,M) + E0
      SUMEX(2,M) = SUMEX(2,M) + PRFIL(5)
      SUMEX(3,M) = SUMEX(3,M) + E8
      SUMEX(4,M) = SUMEX(4,M) + E7
      SUMEX(5,M) = SUMEX(5,M) + PRFIL(1) + PRFIL(3)
      SUMEX(6,M) = SUMEX(6,M) + PRFIL(1)
      SUMEX(7,M) = SUMEX(7,M) + PRFIL(3)
      SUMEX(8,M) = SUMEX(8,M) + E5 + E6
      SUMEX(9,M) = SUMEX(9,M) + E5
```

```
0111          SUMEX(10,M) = SUMEX(10,M) + F6
0112          SUMEX(11,M) = SUMEX(11,M) + PRFIL(2)
0113          SUMEX(12,M) = SUMEX(12,M) + PRFIL(4)
0114          SUMEY(1,M) = SUMEY(1,M) + PRFIL(4)
0115          JCRIT = 2
0116          DO 73  ICRIT = 1,NCRIT
0117          SUMEY(JCRIT,M) = SUMEY(JCRIT,M) + CRPRL4(ICRIT)
0118          JCRIT = JCRIT + 1
0119       73 CONTINUE
0120          CRES(1,M) = EO*HK(1)*CK(1)
0121          CRES(2,M) = EO*CK(4)
0122          CRES(3,M) = CRES(1,M)+CRES(2,M)
0123          TE1 = PRFIL(1)+PRFIL(3)
0124          CRES(4,M) = TE1*HK(2)*CK(2)
0125          CRES(5,M) = TE1*CK(5)
0126          CRES(6,M) =  CRES(4,M)+CRES(5,M)
0127          CRES(7,M)=(PRFIL(2)*HK(3))              *CK(3)
0128          CRES(8,M)=(PRFIL(2))       *CK(6)
0129          CRES(9,M)=CRES(7,M)+CRES(8,M)
0130          CRES(13,M)=(PRFIL(3)    +        F6)*CK(7)
0131          CRES(14,M)=PRFIL(4)*CK(8)
0132          DO 71  IFAILS=1,NFAILS
0133          CRES47 (M,IFAILS) =             (PRFL4(IFAILS)*HK4(IFAILS)) *
         *     CK3(IFAILS)
0134          CRES48 (M,IFAILS) =          (PRFL4(IFAILS))*CK6(IFAILS)
0135          CRES49 (M,IFAILS) = CRES47 (M,IFAILS)+CRES48 (M,IFAILS)
0136          ICRIT = ICR(IFAILS)
0137          CRCR47(M,ICRIT) = CRCR47(M,ICRIT) + CRES47(M,IFAILS)*SYS
0138          CRCR48(M,ICRIT) = CRCR48(M,ICRIT) + CRES48(M,IFAILS)*SYS
0139          CRCR49(M,ICRIT) = CRCR49(M,ICRIT) + CRES49(M,IFAILS)*SYS
0140          CRES(7,M) = CRES(7,M) + CRES47(M,IFAILS)
0141          CRES(8,M) = CRES(8,M) + CRES48(M,IFAILS)
0142          CRES(9,M) = CRES(9,M) + CRES49(M,IFAILS)
0143       71 CONTINUE
0144          CRES(10,M)=CRES(1,M)+CRES(4,M)+CRES(7,M)
0145          CRES(11,M)=CRES(2,M)+CRES(5,M)+CRES(8,M)
0146          CRES(12, M)=CRES(10,M)+CRES(11,M)
0147          CRESHT(1,M) = PRFIL(2) * HK(3) * CK(3)
0148          CRESHT(2,M) = PRFIL(2) * CK(6)
0149          CRESHT(3,M) = CRESHT(1,M) + CRESHT(2,M)
0150          DO 53  K=1,14
0151       53 SUMCO(K,M) = SUMCO(K,M)+CRES(K,M)*SYS
0152          SUMCHT(1,M) = SUMCHT(1,M) + CRESHT(1,M)*SYS
0153          SUMCHT(2,M) = SUMCHT(2,M) + CRESHT(2,M)  *SYS
0154          SUMCHT(3,M) = SUMCHT(3,M) + CRESHT(3,M)*SYS
0155        9 CONTINUE
0156          WRITE (18,201) (ITLE(M),M=1,19),(IENAME(I),I=1,4),IFUNAM,NK
0157          WRITE (18,202)
0158          DO 52  M=1,NLIST
0159          INU = MLIST(M)
0160          WRITE (18,203) INU,ICRES(K,M),K=1,14)
0161       52 CONTINUE
0162          WRITE (19,702) (ITLE(M),M=1,19),(IENAME(I),I=1,4),IFUNAM,NK
0163          WRITE (19,703)  (MODENM,IFAILS=1,NFAILS)
0164          WRITE (19,705) (IFAILS,IFAILS=1,NFAILS)
0165          DO 62  M=1,NLIST
```

```
0166            INU = MLIST(M)
0167            WRITE (19,711) INU,CRESHT(1,M),(CRES47(M,IFAILS),IFAILS=1,NFAILS)
0168            WRITE (19,712) CRESHT(2,M),(CRES48(M,IFAILS),IFAILS=1,NFAILS)
0169            WRITE (19,713) CRESHT(3,M),(CRES49(M,IFAILS),IFAILS=1,NFAILS)
0170         63 CONTINUE
0171         62 CONTINUE
0172            RETURN
0173        101 FORMAT (///,27X,19A4//
               *     15X,10HEQUIPMENT ,4A4,2X,13HFUNCTION CODE,2X,2A4,A3,1X,A2,10X,
               *     23HSTATISTICS FOR MISSIONS,I3,13H COMPONENT(S))
0174        201 FORMAT (1H0,7X,19A4//15X,11H EQUIPMENT ,4A4,
               *     2X,13HFUNCTION CODE,1X,2A4,A3,1X,A2,5X,
               *   28HCOST STATISTICS FOR MISSIONS,I3,13H COMPONENT(S)/)
0175        202 FORMAT (1X,5HMISS ,5H ****,14HSERVICE ACTION,5(1H*),4H ***,
               1  16HPREVENTIVE MAINT,4H****,4H ***,16HCORRECTIVE MAINT,
               2  4H****,1X,8(1H*),5HTOTAL,5(1H*),1X,8HUNAVAIL-,
               *   8H UNRELI-/1X,  5HIONS ,4(24H LABOR  MATERIAL   TOTAL),
               *   7H  ABLE ,8H   ABLE /)
0176        203 FORMAT (1X,I5,14F8.0)
0177        401 FORMAT (1H0,30X,5X,36HEXPECTED MAINTENANCE ACTIONS BY TYPE//
               *     4X,8HMISSIONS,
               *   10H SERVICE  ,10H COMPLETE ,10H INCOMPLET,10H COMPLETE ,
               *   10H INCOMPLET,10H HAND/TRA ,10H MIS FAIL ,10H COMPLETE ,
               *   10H INCOMPLET,
               *   10H    TOTAL /12X,
               *   10H ACTIONS  ,10H   PMA'S  ,10H   PMA'S  ,10H   CMA'S  ,
               *   10H   CMA'S  ,10H   CMA'S  ,10H   CMA'S  ,10H   MA'S   ,
               *   10H  MA'S    ,
               *   10H    MA'S  )
0178        402 FORMAT (1X,I10,10F10.2)
0179        501 FORMAT (13H0VARIANCE NEG,2I5,G16.8)
0180        602 FORMAT (1X,I10,11F10.2)
0181        701 FORMAT (1H0,30X,5X,
               *  55HEXPECTED CORRECTIVE MAINTENANCE ACTIONS BY FAILURE MODE//
               *     4X,8HMISSIONS,10H HAND/TRA ,10(4X,A4,2X))
0182        702 FORMAT (1H1,7X,19A4//10X,11H EQUIPMENT ,4A4,
               *     2X,13HFUNCTION CODE,1X,2A4,A3,1X,A2,1X,
               *   44HCOST STATISTICS FOR MISSIONS BY FAILURE MODE,
               *   I3,13H COMPONENT(S)/)
0183        703 FORMAT(14X,8HMISSIONS,10H HAND/TRA ,10(4X,A4,2X))
0184        704 FORMAT (18X,10I10)
0185        705 FORMAT (8X,22X,10I10)
0186        708 FORMAT (1H0,30X,5X,
               *  59HEXPECTED CORRECTIVE MAINTENANCE ACTIONS BY CRITICALITY CODE//
               *   4X,8HMISSIONS,10H MIS FAIL ,5(4X,A4,2X))
0187        709 FORMAT (14X,5HCMA'S ,5I10)
0188        710 FORMAT (1X,I10,6F10.2)
0189        711 FORMAT (9H0LABOR    ,I10,11F10.0)
0190        712 FORMAT (9H MATERIAL,10X,11F10.0)
0191        713 FORMAT (9H TOTAL    ,10X,11F10.0)
0192            END
```

```
      SUBROUTINE COMP6
C         COMPUTE SPARES
      IMPLICIT REAL * 4 (A-H,O-Z)
      REAL * 4 LA,LA4,LA4SUM
      COMMON T,TAU,XMAR
      COMMON CURVEX(400),CURVEY(400),PCINAM(10,400),CUPNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON XNK,XXK,XXKF
      COMMON ALPHA,PHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
      COMMON AC,AV,RE
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100 )
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON PRODBE(100),A(100,5),ASUM(100,5)
      COMMON HK(5),CK(9),SUMCO(14,10),CPES(14,10),CAUSE( 4,5)
      COMMON POLY(100),PRFIL(5),PRFIL2(5)
      COMMON POLY1(201),POLY2(201),POLY3(201)
      COMMON B(101,10,5)
      COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
      COMMON ITLF(20),NMISS,ICPT1,NTYPES,IPR,   NLIST,MLIST( 10),MSTAPT
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),ICNAME(4)
      COMMON NFAILS,IVENO1(10),IVENO2(10),MCCTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IPFPB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFLNAM(4)
      COMMON ISYS,    NMISP1,MSPAP,MSPAP1
      COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
      COMMON LA(100,5),LA4(100,10),LA4SUM(100),PKLINT(100,10)
      COMMON PREL4(10), FK4(10),  B4(101,10,10),A4(100,10),ASUM4(100,10)
      COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
      COMMON NCRIT,ICP(10),CRCP47(10,5),CRCP48(10,5),CRCP49(10,5)
      COMMON CRPPL4(5),SUMEX(12,10),SUMEY(6,10)
      NTIMES = ISYS*XNK
      IF (MSPAR .NE. 0)  GO TO 51
      TEI = NTIMES
      MSPAP = NTIMES*PRFIL(5)+4.*SQRT(  TEI )*PRFIL2(5)+.5
      IF (MSPAR .GT. 200)  MSPAR = 200
      MSPAP1 = MSPAR + 1
   51 CONTINUE
      NPOLY3 = 1
      POLY3(1) = 1.
      SUM7 = 0.
C     DO 1     M=1,NLIST
      M = NLIST
      IF (NTIMES)   1,1,2
    2 CONTINUE
      NPOLY2 = MINO(MLIST(M)+1,MSPAP1)
      DO 4 K=1,NPOLY2
      POLY2(K) = B(K,M,5)
    4 CONTINUE
      DO 3 J=1,NTIMES
      DO 5 K=1,NPOLY1
      POLY1(K) = POLY3(K)
```

```
0055              NPOLY1 = NPOLY3
0056            5 CONTINUE
0057              CALL PMULT2
0058            3 CONTINUE
0059            1 CONTINUE
0060              WRITE (18,301) (ITLE(K),K=1,19),(ICNAME(K),K=1,4),IFUNAM,
                 *   KTIMES,AMISS,MSPAR
0061              DO 6 K=1,NPOLY3
0062              IF (POLY3(K) .LT. EPS)  GO TO 6
0063              SUM7 = SUM7 + POLY3(K)
0064              KM1 = K - 1
0065              WRITE (18,302) KM1,POLY3(K),SUM7
0066            6 CONTINUE
0067              RETURN
0068          302 FORMAT (I10,2F20.8)
0069          301 FORMAT (///  1X,19A4//
                 *     1X,9HCOMPONENT,4X,4A4,2X,13HFUNCTION CODE,2X,2A4,A3,1X,A2,
                 *                          11H  IS  USED      ,I5,
                 *   16H TIME(S) ON     ,I5,11H MISSION(S),5H WITH,I5,
                 *  13H SPARE(S) MAX//
                 2   4X,6HSPARES,9X,11HPROBABILITY,5X,15HCUM PROBABILITY/ )
0070              END
```

```
      SUBROUTINE PRTCT
      IMPLICIT REAL * 4 (A-H,O-Z)
      REAL * 4 LA,LA4,LA4SUM
      COMMON I,TAU,XMAR
      COMMON CURVEX(400),CURVEY(400),PUINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON XNK,XXK,XXKP
      COMMON ALPHA,RHC,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRF,OMEGA(2)
      COMMON AC,AV,PE
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100   )
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON PRODBE(100),A(100,5),ASUM(100,5)
      COMMON HK(5),CK(9),SUMCO(14,10),CRES(14,10),CAUSE( 4,5)
      COMMON POLY(100),PRFIL(5),PRFIL2(5)
      COMMON POLY1(201),POLY2(201),POLY3(201)
      COMMON B(101,10,5)
      COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
      COMMON ITLE(20),NMISS,ICPT1,NTYPES,IPF,    NLIST,MLIST( 10),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IMI,ITYPES
      COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),ICNAME(4)
      COMMON NFAILS,IVENO1(10),IVENO2(10),MOCTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IREPB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      COMMON ISYS,     NMISP1,MSPAR,MSPAP1
      COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
      COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
      COMMON PRFL4(10), RK4(10),  B4(101,10,10),A4(100,10),ASUM4(100,10)
      COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
      COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
      COMMON CRPRL4(5),SUMEX(12,10),SUMFY(6,10)
      DATA ICRINM/4HCRIT/
      SYS = ISYS
C          PRINT EXPECTED SYSTEM MAINTENANCE ACTIONS
      WRITE (20,801) (ITLE(K),K=1,19),ISYS
      WRITE (20,802)
      WRITE (20,803)
      DO 4  M=1,NLIST
      DO 5  I=1,12
    5 SUMEX(I,M) = SUMEX(I,M) * SYS
      INU = MLIST(M)
    4 WRITE (20,804) INU,(SUMEX(I,M),I=1,12)
C          PRINT SYSTEM COST TOTALS
      WRITE (20,501) (ITLE(K),K=1,19),ISYS
      WRITE (20,102)
      WRITE (20,103) (MLIST(M),(SUMCO(I,M),I=1,14),M=1,NLIST)
C          PRINT SYSTEM CRITICALITY TOTALS
      WRITE (21,701) (ITLE(K),K=1,19),ISYS
      WRITE (21,702) (ICRINM,ICRIT=1,NCRIT)
      WRITE (21,703) (ICRIT,ICRIT=1,NCRIT)
      NCRITP = 1+NCRIT
      DO 2  M=1,NLIST
      DO 3  I=1,NCRITP
```

```
0054              SUMEY(I,M) = SUMEY(I,M) * SYS
0055            3 CONTINUE
0056              INU = MLIST(M)
0057              WRITE (21,704) INU,(SUMEY(I,M),I=1,NCRITP)
0058            2 CONTINUE
C                     PRINT SYSTEM COSTS BY CRITICALITY
0059              WRITE (21,601) (TITLE(K),K=1,19),ISYS
0060              WRITE (21,602) (ICRINM,ICRIT =1,NCRIT)
0061              WRITE (21,603) (ICRIT,ICRIT=1,NCRIT)
0062              DO 1  M=1,NLIST
0063              INU = MLIST(M)
0064              WRITE (21,604) INU,SUMCHT(1,M),(CRCR47(M,ICRIT),ICRIT=1,NCRIT)
0065              WRITE (21,605) SUMCHT(2,M),(CRCR48(M,ICRIT),ICRIT=1,NCRIT)
0066              WRITE (21,606) SUMCHT(3,M),(CRCR49(M,ICRIT),ICRIT=1,NCRIT)
0067            1 CONTINUE
0068          102 FORMAT (1X,5HMISS ,5H ****,14HSERVICE ACTION,5(1H*),4H ***,
                 1  16HPREVENTIVE MAINT,4H****,4H ***,16HCORRECTIVE MAINT,
                 2  4H****,1X,8(1H*),5HTOTAL,9(1H*),1X,8HUNAVAIL-,
                 *    8H UNRELI-/1X,   5HIONS ,4(24H LABOR  MATERIAL    TOTAL),
                 *    7H  ABLE ,8H    ABLE /)
0069          103 FORMAT (1X,I5,14F8.0)
0070          501 FORMAT (1H1,10X,19A4//
                 *   40X,20H SYSTEM SUPPORT COST,1X,I5,10H SYSTEM(S)//)
0071          601 FORMAT (1H1,10X,19A4//20X,
                 *   53HSYSTEM COST FOR CORRECTIVE MAINTENANCE BY CRITICALITY,
                 *     1X,I5,10H SYSTEM(S)/)
0072          602 FORMAT(14X,8HMISSIONS,10H HAND/TRA ,10(4X,A4,2X))
0073          603 FORMAT (28X,10I10)
0074          604 FORMAT (9HOLABOR    ,I1C,11F10.C)
0075          605 FORMAT (9H MATERIAL,10X,11F10.0)
0076          606 FORMAT (9H TOTAL    ,10X,11F10.C)
0077          701 FORMAT (1H1,10X,19A4//15X,
                 *56HEXPECTED TOTAL SYSTEM MAINTENANCE ACTIONS BY CRITICALITY,
                 *     1X,I5,10H SYSTEM(S)/)
0078          702 FORMAT (4X,8HMISSIONS,10H  MIS FAIL,5(4X,A4,2X)/)
0079          703 FORMAT (12X,8H   CMA'S,5I10)
0080          704 FORMAT (1X,I10,11F10.2)
0081          801 FORMAT (1H1,10X,19A4//15X,
                 *     49HEXPECTED TOTAL SYSTEM MAINTENANCE ACTIONS BY TYPE,1X,I5,
                 *     10H SYSTEM(S)/)
0082          802 FORMAT (1X,5HMISS ,10H  SERVICE ,10H   TOTAL  ,10H COMPLETE ,
                 *     10H INCOMPLET,10H   TOTAL  ,10H COMPLETE ,10H INCOMPLET,
                 *     10H    TOTAL  ,10H COMPLETE ,10H INCOMPLET,10H HAND/TRA ,
                 *     10H MIS FAIL  )
0083          803 FORMAT (1X,5HIONS ,10H  ACTIONS ,10H    MA'S  ,10H    MA'S   ,
                 *     10H    MA'S  ,10H   PMA'S  ,10H  PMA'S    ,10H   PMA'S  ,
                 *     5(10H   CMA'S  )/)
0084          804 FORMAT (1X,I5, 12F10.2)
0085              RETURN
0086              END
```

```
      SUBROUTINE PMULTI(P,A,N,IRP1)
C         SUB TO COMPUTE P * A LIMITED TO N TERMS NO CONSTANT
C         N O   C O M M O N
      IMPLICIT REAL * 4 (A-H,O-Z)
      DIMENSION P(100),A(100),PT(100)
      IR = IRP1 - 1
      DO 1 I=IR,N
      PT(I) = P(I)
    1 CONTINUE
      DO 4 I=IRP1,N
    4 P(I) = 0.
      NM1 = N - 1
      DO 2 I=IR,NM1
      TE1 = PT(I)
      J = 1
      K = I + 1
    3 P(K) = P(K) + A(J) * TE1
      J = J + 1
      K = K + 1
      IF (K .LE. N)  GO TO 3
    2 CONTINUE
      DO 5 I = IRP1,N
      IF (P(I) .LT. 1.D -20)  P(I) = 0.
    5 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PMULT2
C           POLY1 * POLY2  GIVING  POLY3
      IMPLICIT REAL * 4 (A-H,O-Z)
      REAL * 4 LA,LA4,LA4SUM
      COMMON T,TAU,XMAR
      COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON XNK,XXK,XXKF
      COMMON ALPHA,RHO,DELTA,LAIT(5),SUMT,           CAPT,DELTT,X(T
      COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
      COMMON AC,AV,RE
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100  )
      COMMON RKLO,SSLIFF,EPS,GAMMA2
      COMMON PRODBE(100),A(100,5),ASLM(100,5)
      COMMON FK(5),CK(9),SUMCO(14,10),CRES(14,10),CAUSE( 4,5)
      COMMON POLY(100),PRF(L15),FRF(L215)
      COMMON POLY1(201),POLY2(201),POLY3(201)
      COMMON B(10,10,5)
      COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
      COMMON ITLE(20),NMISS,ICFT1,NTYPES,IPR,    NLIST,MLIST( 10),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IMI,ITYPES
      COMMON NCURVE,NSIZE(100),ACCPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),ICNAME(4)
      COMMON NFAILS,IVENO1(10),IVENO2(10),MCOTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IRFRB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFLNAM(4)
      COMMON ISYS,     NMISP1,MSPAR,MSPAP1
      COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SLMCHT(3,10)
      COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
      COMMON PREL4(10), HK4(10),  B4(101,10,10),A4(100,10),ASUM4(100,10)
      COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
      COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
      COMMON CRPRL4(5),SLMEX(12,10),SUMEY(6,10)
      NPOLY3 = MIN0(MSPAP1,NPOLY1+NPOLY2-1)
      DO 1 I=1,NPOLY3
    1 POLY3(I) = 0.
      I = 1
    6 IPT = I - 1
      DO 3 J=1,NPOLY2
      IPT = IPT + 1
      IF (IPT - NPOLY3)  4,4,2
    4 POLY3(IPT) = POLY3(IPT) + POLY1(I) * POLY2(J)
    3 CONTINUE
    2 CONTINUE
      I = I + 1
      IF (I .GT. NPOLY1)  GO TO 8
      IF (I .LE. NPOLY3)  GO TO 6
    8 DO 9 I=1,NPOLY3
      IF (POLY3(I) .LT. 1.D-20)  POLY3(I) = 0.D0
    9 CONTINUE
      RETURN
      END
```

```
      FUNCTION COMPRK(TEI,IBFAIL,IEFAIL)
C           COMPUTE RK
      IMPLICIT REAL * 4 (A-H,O-Z)
      REAL * 4 LA,LA4,LA4SUM
      COMMON I,TAU,XMAP
      COMMON CURVEX(400),CURVEY(400),POINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON XNK,XXK,XXKP
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBEE,OMEGA(2)
      COMMON AC,AV,RE
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100  )
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON PROBBE(100),A(100,5),ASUM(100,5)
      COMMON HK(5),CK(5),SUMCC(14,10),CRES(14,10),CAUSE( 4,5)
      COMMON POLY(100),PROIL(5),PROIL2(5)
      COMMON POLY1(201),POLY2(201),POLY3(201)
      COMMON B(10,10,5)
      COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
      COMMON ITLE(20),NMISS,ICFT1,NTYPES,IPR,   NLIST,MLIST( 10),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON J,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
      COMMON IBEG(100),IFNAME(4),ICNAME(4)
      COMMON NFAILS,IVENO1(10),IVENO2(10),MODTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IPERB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      COMMON ISYS,     NMISP1,MSPAR,MSPAP1
      COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
      COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
      COMMON PREL4(10), HK4(10),  B4(10,10,10),A4(100,10),ASUM4(100,10)
      COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
      COMMON NCRIT,ICRI(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
      COMMON CRPRL4(5),SUMEX(12,10),SUMEY(6,10)
      REAL * 8 TE1DUB,S8,F8,EPS8
      DIMENSION AUX(30)
      TF2 = 1.
      DO 2  IFAILS=IBFAIL,IEFAIL
      IF (MODTYP(IFAILS) .EQ. 2)  GO TO 3
      TE3 = CURVE(IVENO1(IFAILS),TE1,0)
      GO TO 7
    3 CONTINUE
C               DO GAUSSIAN QUADRATURE
      I1 = IVENO1(IFAILS)
      I2 = IVENO2(IFAILS)
      TE1DUB = TE1
      EPS8 = EPS
      J = 2
   12 CONTINUE
      CALL AUGAUS(0.D0,TE1DUB, EPS8,S8,J,F8,1.D-5 )
      IF (J-1)  99,11,13
   11 CONTINUE
      X = F8
      F1T = CURVE(I1   , X,0)
      R2T = CURVE(I2,TE1-X,0)
```

```
      ER = FIT * R2T
      GO TO 12
   13 CONTINUE
      RITE1 = CURVFIII,TE1,   C)
      TE3 = RITE1 + S8
    7 CONTINUE
      TE2 = TE2 * TE3
    2 CONTINUE
      COMPRK = TE2
      RETURN
   99 WRITE (6,301) TE1
      STOP
  301 FORMAT (26H0COMPRK CANNOT EVALUATE RK,F16.8)
      END
```

```
0001            SUBROUTINE AUGAUS(A,B,R,S,J,F,PP)
         C                        360-135
0002            DIMENSION XDATX(14),XDATW(14)
0003            REAL * 8 IT,LP,NP,A,B,P,S,F,F,X1,X2,X2PX1,X2MX1,Q6,Q8,XDATX
0004            REAL * 8 XDATW,PP
0005            DATA XDATX/-0.932469514203152,-0.661209386466265,
              1    -0.238619186081397,+0.238619186083197,
              2    0.661209386466265,+0.932469514203152,
              3    -0.960289856497536,-0.796666477413627,
              4    -0.525532409916329,-0.183434642495650,
              5    +0.183434642495650,+0.525532409516329,
              6    +0.796666477413627,+0.960289856497536/
0006            DATA XDATW/+0.171324492379170,+0.360761573048139,
              1    +0.467913934572691,+0.467913934572691,
              2    +0.360761573048139,+0.171324492379170,
              3    +0.101228536290376,+0.222381034453374,
              4    +0.313706645877887,+0.362683783378362,
              5    +0.362683783378362,+0.313706645877887,
              6    +0.222381034453374,+0.101228536290376/
0007            IF (J - 1)  3,4,1
0008          1 IF (J - 2)  3,2,2
0009          3 J = 0
0010            RETURN
0011          2 S =0.D0
0012            IT = 34359738368.DC
0013            J = 1
0014            LR = IT
0015            NR = IT
0016         11 N = 1
0017            X1 = A+((IT-LP)*(B-A))/IT
0018            X2 = X1+NR*(B-A)/IT
0019            X2PX1 = X2 + X1
0020            X2MX1 = X2 - X1
0021            Q6 = 0.0D0
0022            Q8 = 0.0D0
0023            F = (X2MX1*XDATX(N)+X2PX1)*.5D0
0024            RETURN
0025          4 F = F+0.1D-74
0026            IF (N - 6)  5,5,6
0027          5 Q6 = Q6+F*XDATW(N)
0028            N = N + 1
0029            F = (X2MX1*XDATX(N)+X2PX1)*.5D0
0030            RETURN
0031          6 Q8 = Q8+F*XDATW(N)
0032            N = N + 1
0033            IF (N - 14)  7,7,8
0034          7 F = (X2MX1*XDATX(N)+X2PX1)*.5D0
0035            RETURN
0036          8 CONTINUE
0037            IF (DABS(Q8) .LT. RP)  GO TO 9
0038            IF (DABS(Q6-Q8)-P*DABS(Q8))  9,9,10
0039         10 NR = NR * .5D0
0040            IF (NR - 1.0D0)  11,3,11
0041          9 LP = LP - NR
0042            S = S+Q8*(X2-X1)*.5D0
0043            IF (LP)  13,12,13
```

```
      12 J = 2
         RETURN
      13 IF (DABS(Q9) .LT. RP)  GO TO 14
         IF (DABS(Q6-Q8)-R*DABS(Q8)*.125D0)  14,14,111
      14 NR = NR*2.D0
     111 IF (LR - NR)  110,11,11
     110 NR = LR
         GO TO 11
         END
```

```
      FUNCTION COMPIN(BIN,BFI,IB)
      IMPLICIT REAL * 4 (A-H,O-Z)
      REAL * 4 LA,LA4,LA4SUM
      COMMON T,TAU,XMAF
      COMMON CURVEX(400),CURVEY(400),PCINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON XNK,XXK,XXKF
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
      COMMON AC,AV,RF
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100  )
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON FRODBE(100),A(100,5),ASUM(100,5)
      COMMON HK(5),CK(9),SUMCC(14,10),CRES(14,10),CAUSE( 4,5)
      COMMON POLY(100),PRFIL(5),PRFIL2(5)
      COMMON POLY1(201),POLY2(201),POLY3(201)
      COMMON B(101,10,5)
      COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
      COMMON ITLE(20),NMISS,ICPT1,NTYPES,IPP,   NLIST,MLIST( 10),MSTART
      COMMON MISNAM(10),MISCES(20,5)
      COMMON I,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),ICNAME(4)
      COMMON NFAILS,IVENO1(10),IVENO2(10),MODTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IRFRB,ICYC,ICYCM1,JDEL1,JMAX1,JDEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      COMMON ISYS,    NMISP1,MSPAR,MSPAP1
      COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
      COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
      COMMON PREL4(10), RK4(10),  B4(101,10,10),A4(100,10),ASUM4(100,10)
      COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
      COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
      COMMON CRPRL4(5),SUMFX(12,10),SUMFY(6,10)
      REAL * 8 ADUB,BDUB,EPSDUB,S8,F8
      ADUB = BIN
      BDUB = BFI
      EPSDUB = EPS
      J = 2
   12 CONTINUE
      CALL AUGUSZ(ADUB,BDUB,EPSDUB,S8,J,F8,1.D-5)
      IF (J-1)  99,11,13
   11 Y = F8
      F8 = COMPG(Y,IB)
      GO TO 12
   13 COMPIN = S8
      RETURN
   99 WRITE (6,301) BIN,BFI,IB
      STOP
  301 FORMAT (14HOCOMPIN LOOPED,2G16.8,I10)
      END
```

```
      SUBROUTINE AUGUSZ(A,B,R,S,J,F,RP)
      DIMENSION XDATX(14),XDATW(14)
      REAL * 8 IT,LR,NR,A,B,R,S,E,F,X1,X2,X2PX1,X2MX1,Q6,Q8,XDATX
      REAL * 8 XDATW,RP
      DATA XDATX/-0.932469514203152,-0.661209386466265,
     1   -0.238619186081397,+0.238619186083197,
     2   0.661209386466265,+0.932469514203152,
     3   -0.960289856497536,-0.796666477413627,
     4   -0.525532409916329,-0.183434642495650,
     5   +0.183434642495650,+0.525532409916329,
     6   +0.796666477413627,+0.960289856497536/
      DATA XDATW/+0.171324492379170,+0.360761573048139,
     1   +0.467913934572691,+0.467913934572691,
     2   +0.360761573048139,+0.171324492379170,
     3   +0.101228536290376,+0.222381034453374,
     4   +0.313706645877887,+0.362683783378362,
     5   +0.362683783378362,+0.313706645877887,
     6   +0.222381034453374,+0.101228536290376/
      IF (J - 1)  3,4,1
    1 IF (J - 2)  3,2,2
    3 J = 0
      RETURN
    2 S =0.DC
      IT = 34359738368.D0
      J = 1
      LR = IT
      NR = IT
   11 N = 1
      X1 = A+((IT-LR)*(B-A))/IT
      X2 = X1+NR*(B-A)/IT
      X2PX1 = X2 + X1
      X2MX1 = X2 - X1
      Q6 = 0.0D0
      Q8 = 0.0D0
      F = (X2MX1*XDATX(N)+X2PX1)*.5DC
      RETURN
    4 F = F+C.1D-74
      IF (N - 6)  5,5,6
    5 Q6 = Q6+F*XDATW(N)
      N = N + 1
      F = (X2MX1*XDATX(N)+X2PX1)*.5D0
      RETURN
    6 Q8 = Q8+F*XDATW(N)
      N = N + 1
      IF (N - 14)  7,7,8
    7 F = (X2MX1*XDATX(N)+X2PX1)*.5D0
      RETURN
    8 CONTINUE
      IF (DABS(Q8) .LT. RP)  GO TO 9
      IF (DABS(Q6-Q8)-R*DABS(Q8))  9,9,10
   10 NR = NR * .5D0
      IF (NR - 1.0D0)  11,2,11
    9 LR = LR - NR
      S = S+Q8*(X2-X1)*.5D0
      IF (LR)  13,12,13
   12 J = 2
```

```
      RETURN
   13 IF (DABS(Q8) .LT. RP)  GO TO 14
      IF (DABS(Q6-C8)-R*DABS(C8)*.125D0)  14,14,111
   14 NR = NR*2.D0
  111 IF (LR - NR)  110,11,11
  110 NR = LR
      GO TO 11
      END
```

```
      FUNCTION COMPGK(TE1,IH)
      IMPLICIT REAL * 4 (A-H,O-Z)
      REAL * 4 LA,LA4,LA4SUM
      COMMON T,TAU,XMAP
      COMMON CURVEX(400),CURVEY(400),PCINAM(10,400),CURNAM(10,100)
      COMMON WEIBA(400),WEIBB(400)
      COMMON XNK,XXK,XXKF
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
      COMMON AC,AV,PF
      COMMON RHOT,RKL(100 ),BETA(100 ),GAMMA(100   )
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON PROBBE(100),A(100,5),ASLM(100,5)
      COMMON HK(5),CK(9),SUMCC(14,10),CRES(14,10),CAUSE( 4,5)
      COMMON POLY(100),PRFIL(5),PRFIL2(5)
      COMMON POLY1(201),POLY2(201),POLY3(201)
      COMMON B(101,10,5)
      COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
      COMMON ITLE(20),NMISS,ICFT1,NTYPES,IPP,    NLIST,MLIST( 10),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),NCOPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),ICNAME(4)
      COMMON NFAILS,IVENO1(10),IVENO2(10),MODTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IRERB,ICYC,ICYCM1,JCEL1,JMAX1,JCEL2
      COMMON IREAD,IWRITE,IFUNAM(4)
      COMMON ISYS,    NMISP1,MSPAR,MSPAP1
      COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
      COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
      COMMON PRFL4(10), HK4(10),  B4(101,10,10),A4(100,10),ASUM4(100,10)
      COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
      COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
      COMMON CRPRL4(5),SUMEX(12,10),SUMEY(6,10)
      REAL * 8 TE1DUB,S8,F8,EPS8
      DIMENSION AUX(30)
      TE2 = 1.
      DO 2  IFAILS = 1,NFAILS
      IF (MODTYP(IFAILS) .EQ. 2)  GO TO 3
      IF (IFAILS .EQ. IH)  GO TO 62
      TE3 = CURVE(IVENO1(IFAILS),TE1,0)
      GO TO 7
   62 TE3 = CURVE(-IVENO1(IFAILS),TE1,0)
      GO TO 7
    3 CONTINUE
C                     DO GAUSSIAN QUADRATURE
      I1 = IVENO1(IFAILS)
      I2 = IVENO2(IFAILS)
      TE1DUB = TE1
      EPS8 = EPS
      J = 2
   12 CONTINUE
      CALL AUGAUS(0.D0,TE1DUB, EPS8,S8,J,F8,1.D-5 )
      IF (J-1)  99,11,13
   11 CONTINUE
      X = F8
```

```
      FIT = CURVE1-I1  , X,0)
      IF (IFAILS .EQ. 1H)  GO TO 61
      F2T = CURVE(I2,TE1-X,0)
      F8 = FIT * F2T
      GO TO 12
   61 F2T = CURVE1-I2,TE1-X,0)
      F8 = FIT * F2T
      GO TO 12
   13 CONTINUE
      RITE1 = 0.
      IF (IFAILS .NE. 1H)  RITE1 = CURVE(I1,TE1,0)
      TE3 = RITE1 + S8
    7 CONTINUE
      TE2 = TE2 * TE3
    2 CONTINUE
      COMPGK = TE2
      RETURN
   99 WRITE (6,301) TE1
      STOP
  301 FORMAT (26H0COMPGK CANNOT EVALUATE GK,F16.8)
      END
```

```
      FUNCTION CURVE(IX,X,IWETRO)
C         LOOK UP CURVES WITH VALUES BETWEEN 0 AND 1
      IMPLICIT REAL * 4 (A-H,O-Z)
      REAL * 4 LA,LA4,LA4SUM
      COMMON T,TAU,XMAR
      COMMON CURVEX(400),CURVEY(400),PUINAM(10,400),CURNAM(10,100)
      COMMON WEIPA(400),WE(PBI400)
      COMMON XNK,XXK,XXKP
      COMMON ALPHA,RHO,DELTA,UNIT(5),SUMT,          CAPT,DELTT,XIT
      COMMON SUMBAC,SUMBAV,SUMBRE,OMEGA(2)
      COMMON AC,AV,RE
      COMMON RHOT,RKLI(100 ),BETA(100 ),GAMMA(100  )
      COMMON RKLO,SSLIFE,EPS,GAMMA2
      COMMON PRODBE(100),A(100,5),ASUM(100,5)
      COMMON HK(5),CK(9),SUMCO(14,10),CRES(14,10),CAUSE( 4,5)
      COMMON POLY(100),PRF(LI5),PRFIL2(5)
      COMMON POLY1(201),POLY2(201),POLY3(201)
      COMMON B(101,10,5)
      COMMON ALPHAL(100),ALPHAC(100),DELTAL(100)
      COMMON ITLE(20),NMISS,ICFT1,NTYPES,IPR,   NLIST,MLIST( 10),MSTART
      COMMON MISNAM(10),MISDES(20,5)
      COMMON I,IM1,ITYPES
      COMMON NCURVE,NSIZE(100),NCCPT(100),NACC(100)
      COMMON IBEG(100),IENAME(4),IONAME(4)
      COMMON NFAILS,IVENC1(10),IVENC2(10),MCDTYP(10)
      COMMON IALPHA,IBETAC,IGAMM1,IGAMM2
      COMMON IRFRB,ICYC,ICYCM1,JCEL1,JMAX1,JCEL2
      COMMON IREAD,IWRITE,IFLNAM(4)
      COMMON ISYS,    NMISP1,MSPAR,MSPAP1
      COMMON NPOLY1,NPOLY2,NPOLY3,CRESHT(3,10),SUMCHT(3,10)
      COMMON LA(100,5),LA4(100,10),LA4SUM(100),RKLINT(100,10)
      COMMON PRFL4(10), HK4(10),  B4(101,10,10),A4(100,10),ASUM4(100,10)
      COMMON CK3(10),CK6(10),CRES47(10,10),CRES48(10,10),CRES49(10,10)
      COMMON NCRIT,ICR(10),CRCR47(10,5),CRCR48(10,5),CRCR49(10,5)
      COMMON CRPRL4(5),SLMEX(12,10),SUMEY(6,10)
      CURVE = 0.
      IC = IX
      ISWTCH = 0
      IF (IC)  31,2,1
C              CURVE NUMBER NEGATIVE IMPLIES COMPUTE NEGATIVE DERIVATIVE
   31 CONTINUE
      ICABS = -IC
      IF (NCCPT(ICABS))  32,32,33
   32 IC = ICABS + 1
      GO TO 3
   33 IF (NCCPT(ICABS) - 1)  34,34,98
   34 ISWTCH = 1
      IC = ICABS
      GO TO 4
    1 CONTINUE
      IF (NCCPT(IC))  3,3,4
    3 CONTINUE
      ISTORE = IBEG(IC)
      CURVE = YL(N36(NSIZE(IC),CURVEX(ISTORE),CURVEY(ISTORE),XI
    5 IF (ICURVE .LT. 0.   .OR. CURVE .GT. 1.  )  GO TO 99
    2 RETURN
```

```
      4 CONTINUE
        I2 = NSIZE(IC)
        SUM4 = 0.
        SUM5 = 0.
        PROD4 = 1.
        ISTORE = IBEG(IC)
        DO 11 I3=1,I2
        TE10 = WEIBA(ISTORE)*X**WEIBB(ISTORE)
        IF(IWEIBO .EQ. 0) GO TO 21
        IF (TE10 .GT. 100.) GO TO 11
        PROD4 = PROD4*(1.-EXP(-TE10))
        GO TO 11
     21 CONTINUE
        SUM4 = SUM4 + TE10
        IF (ISWTCH .EQ. 0) GO TO 11
        IF (X .EQ. 0.) GO TO 11
        SUM5=SUM5+WEIBA(ISTORE)*WEIBB(ISTORE)*X**(WEIBB(ISTORE)-1.)
     11 CONTINUE
        IF (IWEIBO .EQ. 0) GO TO 22
        CURVE = PROD4
        GO TO 5
     22 CONTINUE
        IF (SUM4 .GT. 100.  ) GO TO 12
        CURVE =  EXP(-SUM4)
        IF (ISWTCH .EQ. 1)  CURVE=CURVE*SUM5
        GO TO 5
     12 CURVE = 0.
        RETURN
     99 WRITE (6,301) IX,X,CURVE,L,J
        STOP
     98 WRITE (6,302) IX,X,IXC2,NCEPT(ICARS)
        STOP
    301 FORMAT (19HOCURVE OUT OF RANGE,I5,G16.8,2I5)
    302 FORMAT (28HONCEPT NOT 0 OR 1 IN RK COMP,I10,F16.8,2I10)
        END
```

```
FORTRAN IV G LEVEL  21                COMPAB             DATE = 76246          18/16/46                PAGE 0001

                   SUBROUTINE COMPAB(XMU,P,A,B,NACC)
                   IMPLICIT REAL *4 (A-H,O-Z)
                   NTIMES = 0
                   PTEST =  EXP(-1.  )
                   BT=2.
                   IF (P .LT. PTEST)  BT=(.5  /PTEST)*P
                   NACCT=NACC
                   TEI = -ALOG(P)
                   CALL WEG(1,BT,NACCT,N)
                 2 CONTINUE
                   IF (NTIMES .GT.  30) GO TO 8
                   TE5 = 1.  /BT
                   BT = .5* GAMMA(TE5)*TEI**(-TE5)
                   NTIMES = NTIMES + 1
                   CALL WEG(2,BT,0,N)
                   IF(N)  1,2,1
                 1 B=BT
                   TE4= GAMMA(1.  /BT+1.  )
                   A=(XMU/TE4)**(-BT)
                   RETURN
                 8 WRITE (6,103) XMU,P,NACC,NTIMES
                   GO TO 1
               103 FORMAT (24HOTROUBLE SOLVING FOR A,B,2G16.8,I5,I5)
                   END
```

```
            SUBROUTINE WFG(I,XNP1,J,N)
C           360 VERSION OF WFG 360-35
            IMPLICIT REAL * 4 (A-H,O-Z)
            GO TO (1,2),I
          1 K = 1
            XBN = XNP1
            XTEMP=10.  **(-J)
            XP = XNP1
            RETURN
          2 GO TO (3,4),K
          3 IF( ABS(XP-XNP1)-XTEMP* ABS(XP)) 5,5,8
          8 XP=XNP1
            XBNM1 = XBN
            XBN = XNP1
            K = 2
          7 XN = XNP1
            XNP1 = XBN
            N = 0
            RETURN
          4 XBNP1 =     ((XNP1*XBNM1)-(XN*XBN))/(XNP1+XBNM1-XN-XBN)
            IF(( ABS (XP-XBNP1))-( ABS (XTEMP*XP)))5,5,6
          6 XP = XBNP1
            XBNM1 = XBN
            XBN = XBNP1
            GO TO 7
          5 N = 1
            RETURN
            END
```

FORTRAN IV G LEVEL 21 YLIN36 DATE = 76246 10/16/46 PAGE 0001

```
      FUNCTION YLIN36(N,XL,YL,X)
      IMPLICIT REAL * 4 (A-H,O-Z)
      DIMENSION XL(10),YL(10)
      IF (N - 1) 5,5,6
    6 DO 1 I=1,N
      IF (X - XL(I)) 3,2,1
    1 CONTINUE
      I = N
      GO TO 4
    3 IF (I.EQ.1) I=2
    4 YLIN36 = YL(I-1) + ((X-XL(I-1))/(XL(I)-XL(I-1))) * (YL(I)-YL(I-1))
      RETURN
    2 YLIN36 = YL(I)
      RETURN
    5 YLIN36 = YL(1)
      RETURN
      END
```

STATISTICS -- 2,186 CARDS READ @ 17.13.39 -- 4,367 LINES PRINTED -- 0 CARDS PUNCHED -- 10.47 WALL CLOCK TIME (MINS)

JOB DECK LISTING WITH TEST DATA
FOR COST/SPARES MODEL

```
//GO.FT05F001 DD *
      TEST OF COST REBUILD                                                          1
    5   1.   1..000001                         TEST OF COST REBUILD
          MISSION = 1     TAU = 1    FAILURE  A=.5     B=1
       ALPHA = .5        BETA = .5
      GAMMA = .5     GAMMA2 =.5
        DELTA = 1       RHO = 1
          COST MISDES
    1   10     1    1
         1
KATHY COMP                     1         1         1         0        0123456789956
KATHY EGPT                 1   1    2    2    2    2    1.   4        YEARS
1  1
    1     1     1     1     1     1     1     1     1     1     1     1     1
/*
//GO.FT09F001 DD *
         2
         1         2         4                   A=.5  B=1
                  .5        1.                   A=.5  B=1
         1         0         4                   .5
                  0.        .5                   .5
/*
//GO.FT06F001 DD SYSOUT=A,DCB=(RECFM=FA,LRECL=133,BLKSIZE=133)
//GO.FT16F001 DD SYSOUT=A,DCB=(RECFM=FA,LRECL=133,BLKSIZE=133)
//GO.FT18F001 DD SYSOUT=A,DCB=(RECFM=FA,LRECL=133,BLKSIZE=133)
//GO.FT20F001 DD SYSOUT=A,DCB=(RECFM=FA,LRECL=133,BLKSIZE=133)
//GO.FT22F001 DD UNIT=SYSDA,DISP=(NEW,PASS),DSN=&&FT22,
//  DCB=(RECFM=VBS,LRECL=20,BLKSIZE=2000),SPACE=(CYL,(1,1))
/*
```

APPENDIX D

ILLUSTRATIVE COMPUTER APPLICATION OF AMSEC METHODOLOGY

The following pages provide a full illustration of the use of AMSEC in its current version. The methodology has been applied to a hypothetical system configuration which is shown schematically in Figure D.1. The components, which are given the names "Little Anna", "Barbara", and "Chloe" for convenience, are considered to be grouped in the series-parallel configuration as shown. The system success requirements, in terms of the number of components which must be operable for reliability purposes, and for availability purposes, are shown in parentheses.

The input parameter values are shown first in data card format (Tables D.1a, D.1b, and D.1c). These inputs are then shown as called up by the computer for review, and component/equipment/system RMACS is displayed. The computer application is organized in the following way:

Table D.2	System Operational Inputs
Table D.3(a)	Input Information, Little Anna
Table D.3(b)	RAM Assessment, Little Anna
Table D.4(a)	Input Information, Barbara
Table D.4(b)	RAM Assessment, Barbara
Table D.5(a)	Input Information, Little Chloe
Table D.5(b)	RAM Assessment, Little Chloe
Table D.6	RAM Assessments for Subsystems
	(a) Anna (2 components)
	(b) Barbara (1 component)
	(c) Chloe (10 components)

Table D.7 RAM Assessment for Systems

Table D.8 System Operational Inputs

Table D.9(a) Input Information, Little Anna

Table D.9(b) Output Cost/Spares, Little Anna

Table D.10(a) Input Information, Barbara

Table D.10(b) Output Cost/Spares, Barbara

Table D.11(a) Input Information, Little Chloe

Table D.11(b) Output Cost/Spares, Little Chloe

Table D.12 System Output for Support Cost

Several explanatory comments regarding these Tables follow. The comments refer to corresponding points in the Tables as annotated by the letters "A", "B", "C", etc. A full list of flagged references is shown as Table D.13.

The handling of multi-mode double stage failure distributions and their combined behavior and impact on component RAC is shown. Component "Barbara" for example, has a two stage failure distribution with respect to a first failure mode and a single stage Weibull with respect to a second mode. Reference "A" shows the composite distribution of survival probability with respect to mode 1. "B" shows the composite distribution of survival probability with respect to mode 2. AMSEC as currently programmed can accept up to 10 failure modes.

A glance at the output columns displaying mission probability of accomplishment, readiness, and reliability demonstrate how the renewal force of maintenance, in combination with the component life characteristics can influence mission readiness and reliability, "C_2" and "C_3" respectively. Little Anna readiness changes little from mission to mission. Her reliability varies a bit over the first half dozen missions, tending to settle down to .72 as missions continue. Readiness for Barbara varies moderately while her reliability remains virtually constant.

Little Chloe demonstrates with her peculiar life and handling habits a dramatic variability in reliability from mission to mission. This variability is amplified as we observe the equipment Chloe. This equipment requires at lease nine little Chloe's out of 10 to be operable at start of mission for readiness and at lease seven little Chloe's to be operable at end of mission for equipment to be mission-reliable. With these requirements we observe for equipment Chloe a tremendous change in reliability from mission to mission and somewhat of a lesser change in readiness. Corrective procedures to correct or reduce such variability would encompass a change

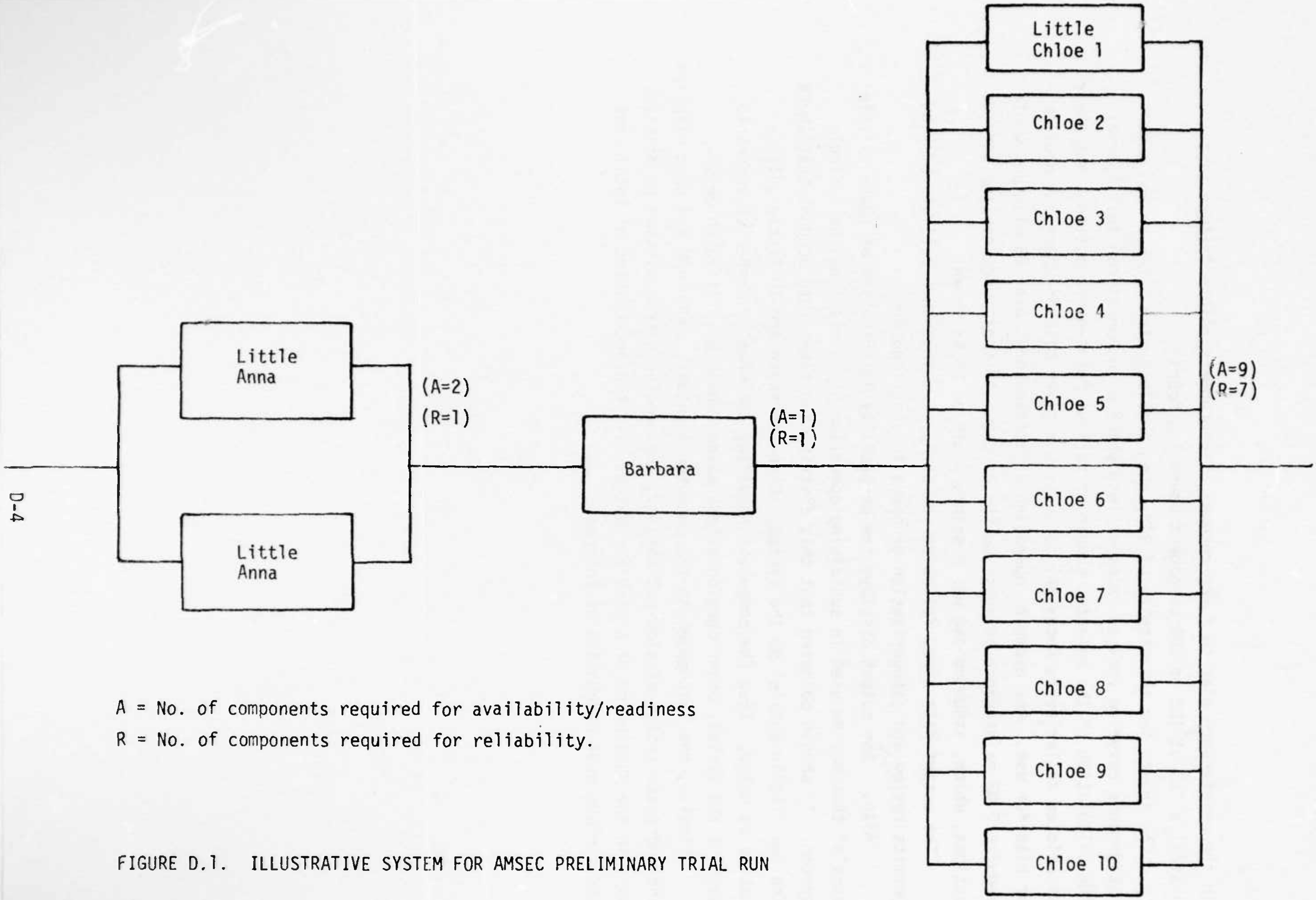
in the maintenance plar to force renewal of components before failure (e.g., install a TBO at 100 or 200 component operating hours).

The inputs for the display of RAM, when combined with man-hour and cost assignments covering various "states" into which a component can fall, permit the calculation of the expected number of various maintenance actions, and their associated dollar costs necessary to sustain a given mission operating profile or plan for use. For example, operating a "little anna" over 25 missions would require 7.03 maintenance actions, on the average; this excludes routine service actions, which, assuming one per mission, would be 25 as shown.

The output data array following the array of maintenance activity by kind permits review and categorization of operating cost centers.

Also, the output displays the probability distribution of spare "little anna's" that may be used in sustaining operation of 25 missions for a single system. It should be noted that this distribution takes into account that there are two "little anna's" on the system. Likewise there are 10 little chloe's making up Chloe. Thus the component requiring the greater number of spares to support the system, other considerations aside, would be "little chloe's".

Finally, the last pages in the computer printouts under RAM and cost displays the aggregate system mission reliability, the readiness from mission to mission; and, in the sustinence of a plan for system use, the aggregation of total cost and various cost categories of interest.



A = No. of components required for availability/readiness

R = No. of components required for reliability.

FIGURE D.1. ILLUSTRATIVE SYSTEM FOR AMSEC PRELIMINARY TRIAL RUN

TABLE D.1. SAMPLE INPUT DATA IN CARD FORMAT[1/]

WORKSHEET FOR EAM KEY PUNCH

CURVE INPUT CARDS (FOR ILLUSTRATIVE SAMPLE RUN)

18				
1	1	4	CURVE 1	LITTLE ANNA
	2	.95	ALPHA	LITTLE ANNA
1	1	4	CURVE 2	LITTLE ANNA
	1	.98	BETA	LITTLE ANNA
1	1	4	CURVE 3	LITTLE ANNA
	1	.98	GAMMA1	LITTLE ANNA
1	1	4	CURVE 4	LITTLE ANNA
	1	.607	GAMMA2	LITTLE ANNA
1	1	4	CURVE 5	LITTLE ANNA
	1000	.90	STAGE 1	LITTLE ANNA
1	1	4	CURVE 6	LITTLE ANNA
	1000	.95	STAGE 2	LITTLE ANNA
1	1	4	CURVE 7	BARBARA
	2	.90	ALPHA	BARBARA
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
1	1	4	CURVE 18	LITTLE CHLOE
	1800	.995	STAGE 1	

1/ See Appendix C for detail explanation of each card.

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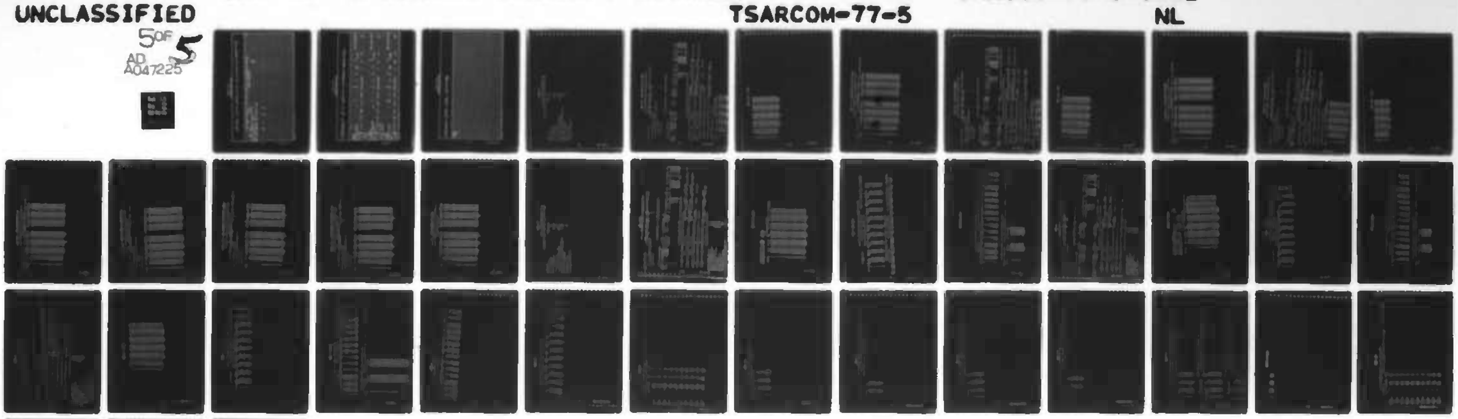

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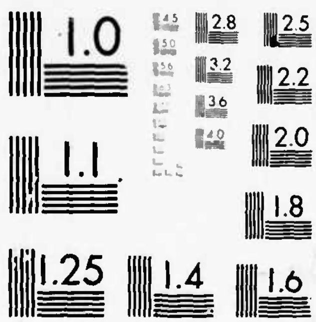

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE D.1 (Cont)

WORKSHEET FOR EAM KEY PUNCH

CONTROL INPUT CARDS (FOR ILLUSTRATIVE SAMPLE RUN)

```
        RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSRATIVE SAMPLE                 0
   25   100    5       .0001                 BOOT STRAP 1
FLIGHT SORTIE TIME (HOURS)                                       2
LANDINGS PER MISSION                                            50
ALL EQUIPMENTS PER SYSTEM GO


    1   25     1    2    2
```

AMC FORM 1734 (Test) (EDITION OF 15 JAN 70 WILL BE USED UNTIL STOCK IS EXHAUSTED)

TABLE D.1 (Cont)

WORKSHEET FOR EAM KEY PUNCH

COMPONENT INPUT CARDS (FOR ILLUSTRATIVE SAMPLE RUN)

```
         3
ANNA                         2         2         1         0       5212345678910
LITTLE ANNA             1    1    1    2    3    4  .98     HOURS
2562
 11.60 11.60 11.60  100. 1000. 2000. 2000.50000.    1.   10.   10.          20
 11.60
 2000.
   10.
BARBARA                      1         1         1         0       3512345678911
LITTLE BARBARA          2    1    7    8    9   10  1.0     HOURS
211122113  1
 11.60 11.60 11.60  100. 1000. 2000. 2000.50000.    1.   10.   10.          20
 11.60 11.60
 2000. 2000.
   10.
CHLOE                       10         9         7         0       3612345678912
LITTLE CHLOE            1  .75   14   15   16   17  .95     HOURS
118  1
 11.60 11.60 11.60  100. 1000. 2000. 2000.50000.    1.   10.   10.          20
 11.60
```

AEC FORM 1730 (Test) EDITION OF 19 JAN 70 WILL BE USED UNTIL STOCK IS EXHAUSTED

TABLE D.1 (Cont'd)

WORKSHEET FOR EAM KEY PUNCH

COMPONENT INPUT CARDS (CONTINUED)

2000.
10.

AMC FORM 1734 (Test) 15 AUG 73 (EDITION OF 15 JAN 70 WILL BE USED UNTIL STOCK IS EXHAUSTED)

TABLE D.2

AMSEC SYSTEM AND MISSION DESCRIPTION

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

MISSION NAME	BOOT STRAP 1
NUMBER OF MISSIONS	25
MISSION LENGTH(HOURS)	100.00
TIME BETWEEN MISSIONS	5.00
SYSTEM SERVICE LIFE (CLOCK HOURS)	2625.00
MISSION ARRIVAL RATE (MISSION/CLOCK HOURS)	0.010
FLIGHT SORTIE TIME(HOURS)	2
LANDINGS PER MISSION	50
ALL EQUIPMENTS PER SYSTEM GO	

TABLE 3(a). INPUT DATA FOR LITTLE ANNA

**********COMPONENT/EQUIPMENT REQUIREMENTS**********

```
EQUIPMENT NAME ANNA            COMPONENT NAME LITTLE ANNA       FUNCTION CODE 52123456789 10
                             UTIL RATE 1.0000    FAILURE ARGUMNT HOURS

   NUMBER OF COMPONENTS IN EQUIPMENT                               2.

   NUMBER OF FUNCTIONING COMPONENTS REQUIRED FOR-

        MISSION READINESS                                          2.

        MISSION SUCCESS                                            1.
```

**********COMPONENT LIFE CHARACTERISTICS**********

```
   NUMBER OF FAILURE MODES          1

NUMBER OF FAILURE STAGES=     2 FOR MODE    1
STAGE    1     USES CURVE NO.      5          CURVE 5    LITTLE ANNA
  PHASE    1     STAGE 1    LITTLE ANNA                  WEIBUL   A=  0.330529E-08 B= 2.7801  MU=    1000.00 PIMU/2)= 0.9000
STAGE    2     USES CURVE NO.      6          CURVE 6   LITTLE ANNA
  PHASE    1     STAGE2    LITTLE ANNA                   WEIBUL   A=  0.426451E-11 B= 3.7348  MU=    1000.00 PIMU/2)= 0.9500
                                                                                1/4 MU=         500.0000     P=   0.99980
                                                                                1/2 MU=        1000.0000     P=   0.98354
                                                                                3/4 MU=        1500.0000     P=   0.84290
                                                                                    MU=        2000.0000     P=   0.49247
                                                                                3/2 MU=        3000.0000     P=   0.02295
                                                                                 2  MU=        4000.0000     P=   0.00003
                                                                                                         A
```

**********MAINTENANCE FREQUENCY CHARACTERISTICS**********

```
   PROBABILITY OF NO PREVENTIVE MAINTENANCE WITH COMPONENT USE(BETA)
                                                         USES CURVE NO.     2 CURVE 2    LITTLE ANNA
  PHASE    1    BETA       LITTLE ANNA                WEIBUL   A=  0.597494E-15 B= 5.0127  MU=    1000.00 PIMU/2)= 0.9800

   PROBABILITY OF INITIATING PREVENTIVE MAINTENANCE WITH COMPONENT USE(GAMMA1)
                                                        USES CURVE NO.     3 CURVE 3    LITTLE ANNA
  PHASE    1    GAMMA1     LITTLE ANNA                WEIBUL   A=  0.597494E-15 B= 5.0127  MU=    1000.00 PIMU/2)= 0.9800

   PROBABILITY OF COMPLETING PREVENTIVE MAINTENANCE(GAMMA2)=  0.993262
                                                         USES CURVE NO.     4 CURVE 4    LITTLE ANNA

   PROBABILITY OF HANDLING/TRANSPORTATION FAILURE(1-DELTA)=  0.020000

   PROBABILITY OF COMPLETING CORRECTIVE MAINTENANCE FOLLOWING MISSION FAILURE(ALPHA)=  1.000000
                                                        USES CURVE NO.     1 CURVE 1    LITTLE ANNA

   COMPONENT REBUILDING CYCLE=    25 (MISSION)
```

MISSION	USAGE	SURVIVAL	PREVENTIVE MAINTENANCE NONE	COMPLETE	INCOMPLETE
1	100.00	1.000000	0.999994	0.000006	0.000000
2	200.00	0.999999	0.999795	0.000203	0.000001
3	300.00	0.999992	0.998440	0.001549	0.000011
4	400.00	0.999952	0.993419	0.006536	0.000044
5	500.00	0.999745	0.974957	0.015865	0.000135
6	600.00	0.999335	0.950853	0.048616	0.000331
		B1	B2	B3	B4

TABLE D.3(a). (Cont)

		B_1	B_2	B_3	B_4
7	700.00	0.998217	0.896604	0.102699	0.000697
8	800.00	0.995850	0.806035	0.190671	0.001293
9	900.00	0.991352	0.680671	0.317177	0.002152
10	1000.00	0.983536	0.520835	0.475937	0.003229
11	1100.00	0.970338	0.349290	0.646325	0.004384
12	1200.00	0.951966	0.196527	0.798059	0.005414
13	1300.00	0.925056	0.088027	0.905829	0.006145
14	1400.00	0.888943	0.029500	0.963961	0.006539
15	1500.00	0.842397	0.006880	0.986429	0.006692
16	1600.00	0.786921	0.001027	0.992242	0.006731
17	1700.00	0.721875	0.000089	0.993173	0.006737
18	1800.00	0.649454	0.000004	0.993258	0.006738
19	1900.00	0.572040	0.000000	0.993262	0.006738
20	2000.00	0.492472	0.000000	0.993262	0.006738
21	2100.00	0.413764	0.000000	0.993262	0.006738
22	2200.00	0.338762	0.000000	0.993262	0.006738
23	2300.00	0.269700	0.000000	0.993262	0.006738
24	2400.00	0.208369	0.000000	0.993262	0.006738
25	2500.00	0.157025	0.000000	0.993262	0.006738

TABLE D.3(b). RAM EVALUATION FOR LITTLE ANNA

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

COMPONENT RESULTS VERSUS AGE

COMPONENT NAME LITTLE ANNA FUNCTION CODE 52123456789 10 UTIL RATE 1.0000 FAILURE ARGUMNT HOURS

MISSION NUMBER	USAGE	MISSION ACCOMPLSH	MISSION READINESS	MISSION RELIABLTY	AVERAGE ACCOMPLSH	AVERAGE READINESS	AVERAGE RELIABLTY
1	100.0	0.980000	0.980000	1.000000	0.980000	0.980000	1.000000
2	200.0	0.979999	0.980000	0.999995	0.980000	0.980000	1.000000
3	300.0	0.979992	0.979999	0.999993	0.979997	0.979999	0.999997
4	400.0	0.979952	0.979950	0.999961	0.979986	0.979997	0.999988
5	500.0	0.979818	0.979960	0.999856	0.979952	0.979989	0.999961
6	600.0	0.979481	0.979880	0.999592	0.979873	0.979971	0.999900
7	700.0	0.978809	0.979717	0.999073	0.979721	0.979935	0.999782
8	800.0	0.977745	0.979444	0.998236	0.979474	0.979873	0.999592
9	900.0	[illegible]76513	0.979089	0.9973[illegible]	0.979145	0.979786	0.999345
10	1000.0	[illegible]	0.978793	0.996[illegible]	0.978807	0.979687	0.999101
11	1100.0	[illegible]976181	0.978772	0.99735[illegible]	0.978568	0.979604	0.998942
12	1200.0	0.977583	0.979103	0.[illegible]8448	0.978486	0.979562	0.998900
13	1300.0	0.971793	0.979524	0.999253	0.978509	0.979559	0.998927
14	1400.0	0.979131	0.979725	0.999394	0.978554	0.979571	0.998961
15	1500.0	0.978999	0.979701	0.999181	0.978577	0.979579	0.998975
16	1600.0	0.978446	0.979583	0.998840	0.978569	0.979580	0.998967
17	1700.0	0.977908	0.979428	0.998447	0.978529	0.979570	0.998935
18	1800.0	0.977412	0.979273	0.998100	0.978466	0.979553	0.998889
19	1900.0	0.977118	0.979159	0.997915	0.978395	0.979532	0.998837
20	2000.0	0.977143	0.979131	0.997970	0.978333	0.979512	0.998793
21	2100.0	0.977471	0.979198	0.998237	0.978291	0.979497	0.998766
22	2200.0	0.977930	0.979326	0.998574	0.978274	0.979489	0.998757
23	2300.0	0.978288	0.979450	0.998813	0.978275	0.979487	0.998759
24	2400.0	0.978399	0.979512	0.998864	0.978280	0.979488	0.998763
25	2500.0	0.978273	0.979498	0.998749	0.978279	0.979488	0.998762
		C_1	C_2	C_3	C_4		

TABLE D.4(a). INPUT DATA FOR BARBARA

**********COMPONENT/EQUIPMENT REQUIREMENTS**********

```
EQUIPMENT NAME BARBARA          COMPONENT NAME LITTLE BARBARA    FUNCTION CODE 35123456789 11
                              UTIL RATE 1.0000   FAILURE ARGUMNT HOURS

   NUMBER OF COMPONENTS IN EQUIPMENT                              1.

   NUMBER OF FUNCTIONING COMPONENTS REQUIRED FOR-

       MISSION READINESS                                          1.

       MISSION SUCCESS                                            1.
```

**********COMPONENT LIFE CHARACTERISTICS**********

```
   NUMBER OF FAILURE MODES         2

NUMBER OF FAILURE STAGES=    2 FOR MODE    1
STAGE    1     USES CURVE NO.    11          CURVE 11  BARBARA
  PHASE    1     STAGE 1   BARBARA                     WEIBUL   A=  0.330529E-08 B= 2.7801  MU=   1000.00 P(MU/2)= 0.9000
STAGE    2     USES CURVE NO.    12          CURVE 12  BARBARA
  PHASE    1     STAGE 2   BARBARA                     WEIBUL   A=  0.200000E-02 B= 1.0000  MU=    500.00 P(MU/2)= 0.6066
                                                                            1/4 MU=      375.0000      P=   0.99202
                                                                            1/2 MU=      750.0000      P=   0.91217
                                                                            3/4 MU=     1125.0000      P=   0.70695
                                                                                MU=     1500.0000      P=   0.44250
                                                                            3/2 MU=     2250.0000      P=   0.11255
                                                                            2   MU=     3000.0000      P=   0.02517
                                                                                                  A
NUMBER OF FAILURE STAGES=    1 FOR MODE    2
STAGE    1     USES CURVE NO.    13          CURVE 13  BARBARA
  PHASE    1     STAGE 1   BARBARA                     WEIBUL   A=  0.613195E-19 B= 5.9876  MU=   1500.00 P(MU/2)= 0.9900
```

**********MAINTENANCE FREQUENCY CHARACTERISTICS**********

```
   PROBABILITY OF NO PREVENTIVE MAINTENANCE WITH COMPONENT USE(BETA)
                                                         USES CURVE NO.      8 CURVE 8   BARBARA
  PHASE    1    BETA     BARBARA                       WEIBUL   A=  0.330529E-08 B= 2.7801  MU=   1000.00 P(MU/2)= 0.9000

   PROBABILITY OF INITIATING PREVENTIVE MAINTENANCE WITH COMPONENT USE(GAMMA1)
                                                         USES CURVE NO.      9 CURVE 9   BARBARA
  PHASE    1    GAMMA1   BARBARA                       WEIBUL   A=  0.330529E-08 B= 2.7801  MU=   1000.00 P(MU/2)= 0.9000

   PROBABILITY OF COMPLETING PREVENTIVE MAINTENANCE(GAMMA2)=  0.792256
                                                         USES CURVE NO.     10 CURVE 10  BARBARA

   PROBABILITY OF HANDLING/TRANSPORTATION FAILURE(1-DELTA)=  0.0

   PROBABILITY OF COMPLETING CORRECTIVE MAINTENANCE FOLLOWING MISSION FAILURE(ALPHA)=  0.999903
                                                         USES CURVE NO.      7 CURVE 7   BARBARA

   COMPONENT REBUILDING CYCLE=   25 (MISSION)
```

MISSION	USAGE	SURVIVAL	PREVENTIVE MAINTENANCE NONE	COMPLETE	INCOMPLETE
1	100.00	0.999739	0.996800	0.000951	0.000249
2	200.00	0.999194	0.991786	0.006508	0.001706
3	300.00	0.996403	0.974858	0.019919	0.005223
		B1	B2	B3	B4

TABLE D.4(a). (CONT)

		B_1	B_2	B_3	B_4
4	400.00	0.989712	0.944917	0.043640	0.011443
5	500.00	0.976942	0.899958	0.079227	0.020775
6	600.00	0.955744	0.839530	0.127133	0.033337
7	700.00	0.923765	0.764527	0.186555	0.048918
8	800.00	0.873863	0.677603	0.255421	0.066976
9	900.00	0.819399	0.582761	0.330560	0.086679
10	1000.00	0.744641	0.484934	0.408064	0.107002
11	1100.00	0.655230	0.389327	0.483809	0.126864
12	1200.00	0.553706	0.300746	0.553988	0.145266
13	1300.00	0.444824	0.222919	0.615647	0.161434
14	1400.00	0.335477	0.158130	0.666977	0.174894
15	1500.00	0.233869	0.107068	0.707431	0.185501
16	1600.00	0.147860	0.069017	0.737577	0.193406
17	1700.00	0.082839	0.042248	0.758785	0.198967
18	1800.00	0.039986	0.024498	0.772847	0.202655
19	1900.00	0.016076	0.013423	0.781621	0.204956
20	2000.00	0.005170	0.006932	0.786764	0.206304
21	2100.00	0.001268	0.003367	0.789588	0.207045
22	2200.00	0.000224	0.001534	0.791041	0.207425
23	2300.00	0.000027	0.000654	0.791738	0.207608

TABLE D.4(b). RAM EVALUATION FOR BARBARA

RAM AMSFC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

COMPONENT RESULTS VERSUS AGE

COMPONENT NAME LITTLE BARBARA FUNCTION CODE 35123456789 11 UTIL RATE 1.0000 FAILURE ARGUMNT HOURS

MISSION NUMBER	USAGE	****** MISSION ****** ACCUMPLSH	READINESS	RELIABLTY	****** AVERAGE ****** ACCUMPLSH	READINESS	RELIABLTY
1	100.0	0.999939	1.000000	C.999939	0.999939	1.000000	0.999939
2	200.0	0.999006	0.999751	0.999255	0.999472	0.999875	0.999597
3	300.0	0.995531	0.998296	0.997229	0.998158	C.999349	0.998808
4	400.0	0.986369	0.994841	0.993495	0.995711	0.998221	0.997479
5	500.0	0.977337	0.989038	0.988170	C.992036	0.996385	0.995617
6	600.0	0.963792	0.981374	C.982085	0.987329	0.993883	0.993362
7	700.0	0.950956	0.973491	0.976851	C.982132	0.990969	0.991003
8	800.0	0.943121	0.967941	0.974358	0.977256	0.988091	0.988922
9	900.0	0.943354	0.966949	C.975599	0.973489	C.985742	0.987442
10	1000.0	0.950850	0.970671	0.979581	0.971225	C.984235	0.986656
11	1100.0	0.960603	0.976529	0.983691	0.970259	0.983534	0.986386
12	1200.0	0.966752	0.980854	C.985623	C.969967	0.983311	0.986322
13	1300.0	0.971274	0.984775	C.986289	0.970068	0.983423	0.986320
14	1400.0	0.963805	0.980345	C.983128	C.969620	0.983203	0.986092
15	1500.0	0.957970	0.976690	0.980833	0.968843	0.982769	0.985741
16	1600.0	0.954669	0.974420	C.97973C	0.967958	0.982247	0.985365
17	1700.0	0.954061	0.973745	0.979784	0.967140	0.981747	0.985036
18	1800.0	0.955483	0.974384	C.980602	0.966492	0.981338	0.984789
19	1900.0	0.957738	0.975678	C.981613	C.966031	C.981040	0.984622
20	2000.0	0.959615	0.976885	0.982322	C.965710	C.980832	0.984507
21	2100.0	0.960382	0.977494	C.982495	0.965456	C.980673	0.984411
22	2200.0	0.959997	0.977394	C.982201	0.9652C7	C.980524	0.984310
23	2300.0	0.958947	0.976822	C.981700	0.964935	0.980363	0.984196
24	2400.0	0.957896	0.976169	0.981281	0.964641	0.980188	0.984074
25	2500.0	0.957334	0.975761	0.981115	0.964348	0.980010	0.983956
		C_1	C_2	C_3		C_4	

TABLE D.5(a). INPUT DATA FOR CHLOE

**********COMPONENT/EQUIPMENT REQUIREMENTS**********

```
EQUIPMENT NAME CHLOE          COMPONENT NAME LITTLE CHLOE       FUNCTION CODE 36123456789 12
                            UTIL RATE 0.7500    FAILURE ARGUMNT HOURS

   NUMBER OF COMPONENTS IN EQUIPMENT                              10.

   NUMBER OF FUNCTIONING COMPONENTS REQUIRED FOR-

        MISSION READINESS                                          9.

        MISSION SUCCESS                                            7.
```

**********COMPONENT LIFE CHARACTERISTICS**********

```
   NUMBER OF FAILURE MODES          1

NUMBER OF FAILURE-STAGES=     1 FOR MODE    1
STAGE    1      USES CURVE NO.    18         CURVE 18   CHLOE
  PHASE    1    LEVNOI      CHLOE                WEIBUL    A=  0.131101E-22 B= 6.9671  MU=    1800.00 P(MU/2)= 0.9950
                                                                                             A
```

**********MAINTENANCE FREQUENCY CHARACTERISTICS**********

```
   PROBABILITY OF NO PREVENTIVE MAINTENANCE WITH COMPONENT USE(BETA)
                                                     USES CURVE NO.    15 CURVE 15   CHLOE
  PHASE    1    BETA       CHLOE                 WEIBUL    A=  0.782774E-16 B= 5.0127  MU=    1500.00 P(MU/2)= 0.9800

   PROBABILITY OF INITIATING PREVENTIVE MAINTENANCE WITH COMPONENT USE(GAMMA1)
                                                    USES CURVE NO.    16 CURVE 16   CHLOE
  PHASE    1    GAMMA 1    CHLOE                 WEIBUL    A=  0.782774E-16 B= 5.0127  MU=    1500.00 P(MU/2)= 0.9800

   PROBABILITY OF COMPLETING PREVENTIVE MAINTENANCE(GAMMA2)=  0.917915
                                                     USES CURVE NO.    17 CURVE 17   CHLOE

   PROBABILITY OF HANDLING/TRANSPORTATION FAILURE(1-DELTA)=  0.050000

   PROBABILITY OF COMPLETING CORRECTIVE MAINTENANCE FOLLOWING MISSION FAILURE(ALPHA)=  0.993262
                                                    USES CURVE NO.    14 CURVE 14   CHLOE

   COMPONENT REBUILDING CYCLE=    25 (MISSION)
```

MISSION	USAGE	SURVIVAL	PREVENTIVE MAINTENANCE NONE	COMPLETE	INCOMPLETE
1	75.00	1.000000	1.000000	0.000000	0.000000
2	150.00	1.000000	0.999794	0.000006	0.000001
3	225.00	1.000000	0.999952	0.000044	0.000004
4	300.00	0.999998	0.999795	0.000188	0.000017
5	375.00	0.999989	0.999374	0.000574	0.000051
6	450.00	0.999960	0.998440	0.001432	0.000128
7	525.00	0.999883	0.996625	0.003098	0.000277
8	600.00	0.999703	0.993419	0.006040	0.000540
9	675.00	0.999325	0.988155	0.010872	0.000972
10	750.00	0.998594	0.979797	0.018361	0.001642
11	825.00	0.997270	0.967944	0.029425	0.002631
12	900.00	0.995000	0.950853	0.045113	0.004034
13	975.00	0.991284	0.927489	0.066557	0.005952
14	1050.00	0.985437	[illegible]	0.094907	[illegible]
		B1	B2	B3	B4

TABLE D.5(a). (Cont)

		B_1	B_2	B_3	B_4
15	1125.00	0.976555	0.857073	0.131195	0.011732
16	1200.00	0.963489	0.808038	0.176205	0.015757
17	1275.00	0.944337	0.749132	0.230275	0.020593
18	1350.00	0.916971	0.680675	0.293113	0.026212
19	1425.00	0.884125	0.603854	0.363628	0.032518
20	1500.00	0.838569	0.520835	0.439833	0.039332
21	1575.00	0.780880	0.434716	0.518882	0.046401
22	1650.00	0.710339	0.349296	0.597291	0.053413
23	1725.00	0.627403	0.268642	0.671324	0.060034
24	1800.00	0.534152	0.196527	0.737519	0.065953
25	1875.00	0.434584	0.135828	0.793237	0.070936

TABLE D.5(b). RAM EVALUATION FOR CHLOE

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

COMPONENT RESULTS VERSUS AGE

COMPONENT NAME LITTLE CHLOE FUNCTION CODE 36123456789 12 UTIL RATE 0.7500 FAILURE ARGUMNT HOURS

MISSION NUMBER	USAGE	*********** MISSION ********** ACCUMPLSH	READINESS	RELIABLTY	*********** AVERAGE ********** ACCUMPLSH	READINESS	RELIABLTY
1	75.0	0.950000	0.950000	1.000000	0.950000	0.950000	1.000000
2	150.0	0.949680	0.949680	1.000000	0.949840	0.949840	1.000000
3	225.0	0.949677	0.949677	1.000000	0.949785	0.949785	1.000000
4	300.0	0.949673	0.949674	0.999998	0.949757	0.949757	0.999999
5	375.0	0.949657	0.949665	0.999993	0.949737	0.949739	0.999998
6	450.0	0.949617	0.949639	0.999977	0.949717	0.949722	0.999994
7	525.0	0.949530	0.949585	0.999942	0.949650	0.949702	0.999987
8	600.0	0.949363	0.949486	0.999870	0.949649	0.949675	0.999972
9	675.0	0.949076	0.949321	0.999741	0.949586	0.949636	0.999946
10	750.0	0.948617	0.949066	0.999527	0.949489	0.949579	0.999904
11	825.0	0.947935	0.948699	0.999195	0.949348	0.949499	0.999840
12	900.0	0.946988	0.948203	0.998719	0.949151	0.949391	0.999746
13	975.0	0.945762	0.947578	0.998084	0.948890	0.949251	0.999619
14	1050.0	0.944300	0.946849	0.997309	0.948562	0.949080	0.999454
15	1125.0	0.942732	0.946081	0.996460	0.948174	0.948880	0.999254
16	1200.0	0.941286	0.945383	0.995666	0.947743	0.948661	0.999030
17	1275.0	0.940268	0.944894	0.995105	0.947303	0.948439	0.998798
18	1350.0	0.939969	0.944746	0.994944	0.946895	0.948233	0.998583
19	1425.0	0.940523	0.945002	0.995261	0.946560	0.948062	0.998408
20	1500.0	0.941787	0.945601	0.995966	0.946320	0.947939	0.998286
21	1575.0	0.943344	0.946357	0.996816	0.946178	0.947863	0.998215
22	1650.0	0.944697	0.947036	0.997530	0.946110	0.947825	0.998184
23	1725.0	0.945537	0.947477	0.997952	0.946085	0.947809	0.998174
24	1800.0	0.945852	0.947656	0.998096	0.946075	0.947802	0.998170
25	1875.0	0.945817	0.947648	0.998067	0.946064	0.947796	0.998166
		C_1	C_2	C_3		C_4	

TABLE D.6(a). RAM ASSESSMENT FOR SUBSYSTEM ANNA

RAM AMSFC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT RESULTS VERSUS AGE

COMPONENT NAME LITTLE ANNA FUNCTION CODE 52123456789 10
EQUIPMENT NAME ANNA UTIL RATE 1.0000 FAILURE ARGUMNT HOURS

NUMBER OF COMPONENTS IN EQUIPMENT 2.

NUMBER OF FUNCTIONING COMPONENTS REQUIRED FOR-

MISSION READINESS 2.

MISSION SUCCESS 1.

MISSION NUMBER	USAGE	*********** MISSION ********** ACCOMPLSH	READINESS	RELIABLTY	*********** AVERAGE ********** ACCOMPLSH	READINESS	RELIABLTY
1	100.0	0.960400	0.960400	1.000000	0.960400	0.960400	1.000000
2	200.0	0.960400	0.960400	1.000000	0.960400	0.960400	1.000000
3	300.0	0.960397	0.960397	1.000000	0.960399	0.960399	0.999999
4	400.0	0.960381	0.960381	1.000000	0.960394	0.960394	0.999999
5	500.0	0.960321	0.960321	1.000000	0.960379	0.960379	0.999999
6	600.0	0.960166	0.960166	1.000000	0.960344	0.960344	0.999999
7	700.0	0.959845	0.959846	0.999999	0.960272	0.960272	0.999999
8	800.0	0.959307	0.959310	0.999997	0.960152	0.960152	0.999999
9	900.0	0.958609	0.958616	0.999993	0.959980	0.959981	0.999998
10	1000.0	0.958026	0.958035	0.999990	0.959785	0.959787	0.999997
11	1100.0	0.957989	0.957995	0.999993	0.959621	0.959624	0.999997
12	1200.0	0.958640	0.958642	0.999997	0.959540	0.959542	0.999997
13	1300.0	0.959467	0.959468	0.999999	0.959534	0.959536	0.999997
14	1400.0	0.959861	0.959861	1.000000	0.959557	0.959559	0.999997
15	1500.0	0.959814	0.959815	0.999999	0.959574	0.959576	0.999997
16	1600.0	0.959582	0.959583	0.999999	0.959575	0.959577	0.999997
17	1700.0	0.959278	0.959280	0.999998	0.959557	0.959559	0.999997
18	1800.0	0.958971	0.958975	0.999996	0.959524	0.959526	0.999997
19	1900.0	0.958749	0.958753	0.999996	0.959483	0.959485	0.999996
20	2000.0	0.958692	0.958697	0.999996	0.959443	0.959445	0.999995
21	2100.0	0.958826	0.958829	0.999997	0.959413	0.959415	0.999995
22	2200.0	0.959078	0.959080	0.999998	0.959398	0.959400	0.999994
23	2300.0	0.959322	0.959323	0.999998	0.959394	0.959396	0.999994
24	2400.0	0.959443	0.959445	0.999999	0.959396	0.959398	0.999994
25	2500.0	0.959416	0.959417	0.999998	0.959397	0.959399	0.999993
		C_1	C_2	C_3		C_4	

TABLE D.6(b). RAM ASSESSMENT FOR SUBSYSTEM BARBARA

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT RESULTS VERSUS AGE

COMPONENT NAME LITTLE BARBARA   FUNCTION CODE 35123456789 11

EQUIPMENT NAME BARBARA   UTIL RATE 1.0000   FAILURE ARGUMNT HOURS

NUMBER OF COMPONENTS IN EQUIPMENT   1.

NUMBER OF FUNCTIONING COMPONENTS REQUIRED FOR-

MISSION READINESS   1.

MISSION SUCCESS   1.

MISSION NUMBER	USAGE	********** MISSION ********** ACCOMPLSH	READINESS	RELIABLTY	********** AVERAGE ********** ACCOMPLSH	READINESS	RELIABLTY
1	100.0	0.999939	1.000000	0.999939	0.999939	1.000000	0.999939
2	200.0	0.999006	0.999751	0.999255	0.999472	0.999875	0.999597
3	300.0	0.995531	0.998296	0.997229	0.998158	0.999349	0.998808
4	400.0	0.988369	0.994841	0.993495	0.995711	0.998221	0.997479
5	500.0	0.977337	0.989038	0.988170	0.992036	0.996385	0.995617
6	600.0	0.963792	0.981374	0.982085	0.987329	0.993883	0.993362
7	700.0	0.950956	0.973491	0.976851	0.982132	0.990969	0.991003
8	800.0	0.943121	0.967941	0.974358	0.977256	0.988091	0.988922
9	900.0	0.943354	0.966949	0.975599	0.973489	0.985742	0.987442
10	1000.0	0.950350	0.970671	0.979581	0.971225	0.984235	0.986656
11	1100.0	0.960603	0.976529	0.983691	0.970259	0.983534	0.986386
12	1200.0	0.966752	0.980854	0.985623	0.969967	0.983311	0.986322
13	1300.0	0.971274	0.984775	0.986289	0.970068	0.983423	0.986320
14	1400.0	0.963805	0.980345	0.983128	0.969620	0.983203	0.986092
15	1500.0	0.957970	0.976690	0.980833	0.968843	0.982769	0.985741
16	1600.0	0.954669	0.974420	0.979730	0.967958	0.982247	0.985365
17	1700.0	0.954061	0.973745	0.979784	0.967140	0.981747	0.985036
18	1800.0	0.955483	0.974384	0.980602	0.966492	0.981338	0.984789
19	1900.0	0.957738	0.975678	0.981613	0.966031	0.981040	0.984622
20	2000.0	0.959615	0.976885	0.982322	0.965710	0.980832	0.984507
21	2100.0	0.960382	0.977494	0.982495	0.965456	0.980673	0.984411
22	2200.0	0.959397	0.977394	0.982201	0.965207	0.980524	0.984310
23	2300.0	0.958947	0.976822	0.981700	0.964935	0.980363	0.984196
24	2400.0	0.957896	0.976169	0.981281	0.964641	0.980188	0.984074
25	2500.0	0.957334	0.975761	0.981115	0.964348	0.980010	0.983956
		C_1	C_2	C_3	C_4		

TABLE D.6(c). RAM ASSESSMENT FOR SUBSYSTEM CHLOE

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT RESULTS VERSUS AGE

COMPONENT NAME LITTLE CHLOE FUNCTION CODE 36123456789 12

EQUIPMENT NAME CHLOE UTIL RATE 0.7500 FAILURE ARGUMNT HOURS

NUMBER OF COMPONENTS IN EQUIPMENT 10.

NUMBER OF FUNCTIONING COMPONENTS REQUIRED FOR-

MISSION READINESS 9.

MISSION SUCCESS 7.

MISSION NUMBER	USAGE	*********** MISSION ********** ACCOMPLSH	READINESS	RELIABLTY	*********** AVERAGE ********** ACCOMPLSH	READINESS	RELIABLTY
1	75.0	0.913862	0.913862	1.000000	0.913862	0.913862	1.000000
2	150.0	0.912904	0.912904	1.000000	0.913383	0.913383	1.000000
3	225.0	0.912896	0.912897	1.000000	0.913220	0.913220	1.000000
4	300.0	0.912888	0.912888	1.000000	0.913137	0.913137	1.000000
5	375.0	0.912858	0.912858	1.000000	0.913081	0.913081	0.999999
6	450.0	0.912782	0.912782	1.000000	0.913031	0.913031	0.999999
7	525.0	0.912621	0.912621	1.000000	0.912973	0.912973	0.999999
8	600.0	0.912324	0.912324	1.000000	0.912892	0.912892	0.999999
9	675.0	0.911827	0.911827	1.000000	0.912773	0.912773	0.999999
10	750.0	0.911059	0.911059	1.000000	0.912602	0.912602	0.999999
11	825.0	0.909948	0.909948	1.000000	0.912360	0.912360	0.999999
12	900.0	0.908442	0.908442	1.000000	0.912034	0.912034	0.999999
13	975.0	0.906530	0.906530	1.000000	0.911610	0.911610	0.999999
14	1050.0	0.904286	0.904286	0.999999	0.911087	0.911087	0.999999
15	1125.0	0.901904	0.901905	0.999998	0.910475	0.910475	0.999999
16	1200.0	0.899721	0.899723	0.999997	0.909803	0.909803	0.999999
17	1275.0	0.898182	0.898185	0.999996	0.909119	0.909119	0.999998
18	1350.0	0.897714	0.897718	0.999996	0.908485	0.908485	0.999997
19	1425.0	0.898522	0.898525	0.999997	0.907961	0.907961	0.999997
20	1500.0	0.900404	0.900406	0.999998	0.907582	0.907583	0.999996
21	1575.0	0.902763	0.902764	0.999999	0.907352	0.907353	0.999996
22	1650.0	0.904865	0.904865	0.999999	0.907239	0.907240	0.999995
23	1725.0	0.906221	0.906222	1.000000	0.907195	0.907195	0.999995
24	1800.0	0.906771	0.906771	1.000000	0.907177	0.907178	0.999994
25	1875.0	0.906747	0.906747	1.000000	0.907159	0.907160	0.999994
		C_1	C_2	C_3		C_4	

TABLE D.7. RAM ASSESSMENT FOR SYSTEM

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

SYSTEM RESULTS VERSUS AGE

MISSION NUMBER	USAGE	********** MISSION ACCOMPLSH	READINESS	********** RELIABLTY	********** AVERAGE ACCOMPLSH	READINESS	********** RELIABLTY
1	100.0	0.877619	0.877673	0.999939	0.877619	0.877673	0.999939
2	200.0	0.875882	0.876534	0.999255	0.876750	0.877103	0.999597
3	300.0	0.872825	0.875250	0.997229	0.875441	0.876485	0.998807
4	400.0	0.866523	0.872197	0.993494	0.873211	0.875413	0.997479
5	500.0	0.856770	0.867027	0.988169	0.869923	0.873736	0.995617
6	600.0	0.844688	0.860097	0.982085	0.865717	0.871462	0.993361
7	700.0	0.833013	0.852754	0.976850	0.861045	0.868790	0.991003
8	800.0	0.825418	0.847143	0.974355	0.856592	0.866084	0.988922
9	900.0	0.824572	0.845202	0.975592	0.853034	0.863764	0.987441
10	1000.0	0.829919	0.847227	0.979571	0.850722	0.862110	0.986654
11	1100.0	0.837376	0.851266	0.983684	0.849509	0.861124	0.986383
12	1200.0	0.841913	0.854196	0.985620	0.848876	0.860547	0.986320
13	1300.0	0.844799	0.853544	0.986288	0.848562	0.860239	0.986317
14	1400.0	0.836572	0.850929	0.983127	0.847706	0.859574	0.986089
15	1500.0	0.829276	0.845483	0.980831	0.846477	0.858634	0.985739
16	1600.0	0.824218	0.841274	0.979726	0.845086	0.857549	0.985363
17	1700.0	0.822024	0.838990	0.979778	0.843729	0.856457	0.985034
18	1800.0	0.822559	0.838837	0.980594	0.842553	0.855479	0.984787
19	1900.0	0.825050	0.840510	0.981606	0.841632	0.854691	0.984619
20	2000.0	0.828350	0.843263	0.982315	0.840968	0.854119	0.984504
21	2100.0	0.831299	0.846114	0.982490	0.840507	0.853737	0.984408
22	2200.0	0.833120	0.848221	0.982198	0.840171	0.853486	0.984307
23	2300.0	0.833668	0.849209	0.981698	0.839888	0.853299	0.984193
24	2400.0	0.833365	0.849264	0.981279	0.839616	0.853131	0.984072
25	2500.0	0.832830	0.848862	0.981113	0.839344	0.852960	0.983953
		C_1	C_2	C_3	C_4		

TABLE D.8

AMSEC SYSTEM AND MISSION DESCRIPTION

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

MISSION NAME	BOOT STRAP 1
NUMBER OF MISSIONS	25
MISSION LENGTH(HOURS)	100.00
TIME BETWEEN MISSIONS	5.00
SYSTEM SERVICE LIFE (CLOCK HOURS)	2625.00
MISSION ARRIVAL RATE (MISSION/CLOCK HOURS)	0.010
FLIGHT SORTIE TIME(HOURS)	2
LANDINGS PER MISSION	50
ALL EQUIPMENTS PER SYSTEM GO	

TABLE D.9(a)

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**********COMPONENT/EQUIPMENT REQUIREMENTS**********

EQUIPMENT NAME ANNA          COMPONENT NAME LITTLE ANNA       FUNCTION CODE 52123456789 10
                           UTIL RATE 1.0000   FAILURE ARGUMNT HOURS

   NUMBER OF COMPONENTS IN EQUIPMENT                         2.

   MAXIMUM SPARES                                            0

                    **********COMPONENT LIFE CHARACTERISTICS**********

   NUMBER OF FAILURE MODES        1

NUMBER OF FAILURE STAGES=    2 FOR MODE     1     CRITICALITY=    2
STAGE    1     USES CURVE NO.     5          CURVE 5    LITTLE ANNA
                  STAGE 1    LITTLE ANNA                 WEIBUL   A=  0.330529E-08 B= 2.7801  MU=    1000.00 P(MU/2)= 0.9000
STAGE    2     USES CURVE NO.     6          CURVE 6   LITTLE ANNA
                  STAGE2    LITTLE ANNA                  WEIBUL   A=  0.426451E-11 B= 3.7348  MU=    1000.00 P(MU/2)= 0.9500
                                                                              1/4 MU=          500.0000      P=   0.99980
                                                                              1/2 MU=         1000.0000      P=   0.98354
                                                                              3/4 MU=         1500.0000      P=   0.84290
                                                                                  MU=         2000.0000      P=   0.49247
                                                                              3/2 MU=         3000.0000      P=   0.02295
                                                                              2   MU=         4000.0000      P=   0.00003
                                                                                                         A
                 **********MAINTENANCE FREQUENCY CHARACTERISTICS**********

   PRC ABILITY OF NO PREVENTIVE MAINTENANCE WITH COMPONENT USE(BETA)
                                                          USES CURVE NO.     2 CURVE 2    LITTLE ANNA
                  BETA       LITTLE ANNA                 WEIBUL   A=  0.597494E-15 B= 5.0127  MU=    1000.00 P(MU/2)= 0.9800

   PROBABILITY OF INITIATING PREVENTIVE MAINTENANCE WITH COMPONENT USE(GAMMA1)
                                                         USES CURVE NO.     3 CURVE 3    LITTLE ANNA
                  GAMMA1     LITTLE ANNA                 WEIBUL   A=  0.597494E-15 B= 5.0127  MU=    1000.00 P(MU/2)= 0.9800

   PROBABILITY OF COMPLETING PREVENTIVE MAINTENANCE(GAMMA2)=   0.993262
                                                          USES CURVE NO.     4 CURVE 4    LITTLE ANNA

   PROBABILITY OF HANDLING/TRANSPORTATION FAILURE(1-DELTA)=  0.020000

   PROBABILITY OF COMPLETING CORRECTIVE MAINTENANCE FOLLOWING MISSION FAILURE(ALPHA)=  1.000000
                                                         USES CURVE NO.     1 CURVE 1    LITTLE ANNA

                 **********COST AND HOURS DATA**********

COST PER SERVICE MAN HOUR                              11.60
COST PER PM MAN HOUR                                   11.60
COST PER CM MAN HOUR FOR H/T                           11.60
MATERIAL COST PER SERVICE                             100.00
MATERIAL COST PER PM                                 1000.00
MATERIAL COST PER CM FOR H/T                         2000.00
COST UNAVAILABLE                                     2000.00
COST UNRELIABLE                                     50000.00
MAN HOURS PER SERVICE                                   1.00
MAN HOURS PER PM                                       10.00
MAN HOURS PER H/T FAILURE                              10.00
MAN HOURS PER MISSION FAILURE(NOT USED)                 0.0
OPERATING INTERVAL PER SERVICE ACTION                  20.00
```

TABLE D.9(a) (Cont)

COST PER CM MAN HOUR BY MODE 11.600
MATERIAL COST PER CM BY MODE 2000.000
MAN HOURS MISS FAIL BY MODE 10.000

MISSION	USAGE	SURVIVAL	PREVENTIVE MAINTENANCE NONE	COMPLETE	INCOMPLETE	MODE INTEGRALS
1	100.00	1.000000	0.999994	0.000006	0.000000	0.0000
2	200.00	0.999999	0.999795	0.000203	0.000001	0.0000
3	300.00	0.999952	0.998440	0.001549	0.000011	0.0000
4	400.00	0.999952	0.993419	0.006536	0.000044	0.0000
5	500.00	0.999755	0.979597	0.019869	0.000135	0.0002
6	600.00	0.999335	0.950853	0.048816	0.000331	0.0005
7	700.00	0.998217	0.896604	0.102699	0.000697	0.0011
8	800.00	0.995850	0.808035	0.190671	0.001293	0.0024
9	900.00	0.991352	0.680671	0.317177	0.002152	0.0045
10	1000.00	0.983536	0.520835	0.475937	0.003229	0.0078
11	1100.00	0.970938	0.349290	0.646325	0.004384	0.0126
12	1200.00	0.951966	0.196527	0.798059	0.005414	0.0190
13	1300.00	0.925056	0.088027	0.905829	0.006145	0.0269
14	1400.00	0.888943	0.029530	0.963961	0.006539	0.0361
15	1500.00	0.842897	0.006880	0.986429	0.006692	0.0461
16	1600.00	0.786921	0.001027	0.992242	0.006731	0.0560
17	1700.00	0.721875	0.000089	0.993173	0.006737	0.0650
18	1800.00	0.649454	0.000004	0.993258	0.006738	0.0724
19	1900.00	0.572040	0.000000	0.993262	0.006738	0.0774
20	2000.00	0.492472	0.000000	0.993262	0.006738	0.0796
21	2100.00	0.413764	0.000000	0.993262	0.006738	0.0787
22	2200.00	0.338762	0.000000	0.993262	0.006738	0.0749
23	2300.00	0.269900	0.000000	0.993262	0.006738	0.0686
24	2400.00	0.208969	0.000000	0.993262	0.006738	0.0606
25	2500.00	0.157025	0.000000	0.993262	0.006738	0.0514
		B_1	B_2	B_3	B_4	

TABLE D.9(b) (Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT ANNA FUNCTION CODE 52123456789 10 STATISTICS FOR MISSIONS 2 COMPONENT(S)

EXPECTED MAINTENANCE ACTIONS BY TYPE

MISSIONS	SERVICE ACTIONS	COMPLETE PMA'S	INCOMPLET PMA'S	COMPLETE CMA'S	INCOMPLET CMA'S	HAND/TRA CMA'S	MIS FAIL CMA'S	COMPLETE MA'S	INCOMPLET MA'S	TOTAL MA'S
1	10.00	0.00	0.0	0.04	0.0	0.04	0.00	0.04	0.0	0.04
2	20.00	0.00	0.00	0.08	0.0	0.08	0.00	0.08	0.00	0.08
3	30.00	0.00	0.00	0.12	0.0	0.12	0.00	0.12	0.00	0.12
4	40.00	0.02	0.00	0.16	0.0	0.16	0.00	0.18	0.00	0.18
5	50.00	0.05	0.00	0.20	0.0	0.20	0.00	0.25	0.00	0.25
6	60.00	0.14	0.00	0.24	0.0	0.24	0.00	0.38	0.00	0.38
7	70.00	0.30	0.00	0.28	0.0	0.28	0.00	0.59	0.00	0.59
8	80.00	0.58	0.00	0.33	0.0	0.32	0.01	0.90	0.00	0.91
9	90.00	0.94	0.00	0.37	0.0	0.36	0.01	1.31	0.00	1.32
25	250.00	4.00	0.03	1.06	0.0	1.00	0.06	5.06	0.03	5.09

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT ANNA FUNCTION CODE 52123456789 10 COST STATISTICS FOR MISSIONS 2 COMPONENT(S)

MISS IONS	****SERVICE ACTION***** LABOR	MATERIAL	TOTAL	***PREVENTIVE MAINT**** LABOR	MATERIAL	TOTAL	***CORRECTIVE MAINT**** LABOR	MATERIAL	TOTAL	********TOTAL********* LABOR	MATERIAL	TOTAL	UNAVAIL-ABLE	UNRELI-ABLE

TABLE D.9(b) Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT ANNA FUNCTION CODE 52123456789 1) COST STATISTICS FOR MISSIONS 2 COMPONENT(S)

MISS IONS	****SERVICE ACTION***** LABOR	MATERIAL	TOTAL	***PREVENTIVE MAINT**** LABOR	MATERIAL	TOTAL	***CORRECTIVE MAINT**** LABOR	MATERIAL	TOTAL	********TOTAL********* LABOR	MATERIAL	TOTAL	UNAVAIL- ABLE	UNRELI- ABLE
1	116.	1000.	1116.	0.	0.	0.	5.	80.	85.	121.	1080.	1201.	0.	0.
2	232.	2000.	2232.	0.	0.	0.	9.	160.	169.	241.	2160.	2402.	0.	0.
3	348.	3000.	3348.	0.	3.	4.	14.	240.	254.	362.	3243.	3606.	0.	1.
4	464.	4000.	4464.	2.	15.	17.	19.	320.	339.	484.	4336.	4820.	0.	4.
5	580.	5000.	5580.	6.	51.	57.	23.	401.	424.	609.	5452.	6061.	0.	19.
6	696.	6000.	6696.	16.	137.	153.	28.	482.	510.	740.	6619.	7359.	1.	59.
7	812.	7000.	7812.	35.	305.	340.	33.	566.	599.	880.	7870.	8751.	2.	149.
8	928.	8000.	8928.	67.	580.	647.	38.	653.	691.	1033.	9232.	10265.	4.	319.
9	1044.	9000.	10044.	110.	945.	1054.	43.	743.	786.	1197.	10687.	11884.	8.	577.
25	2900.	25000.	27900.	467.	4028.	4495.	123.	2120.	2243.	3490.	31147.	34637.	52.	3021.

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

COMPONENT LITTLE ANNA FUNCTION CODE 52123456789 10 IS USED 4 TIME(S) ON 25 MISSION(S) WITH 25 SPARE(S) MAX

SPARES	PROBABILITY	CUM PROBABILITY
7	0.00022228	0.00022228
8	0.07598603	0.07620829
9	0.23762965	0.31383795
10	0.31367493	0.62751287
11	0.22913784	0.85665071
12	0.10364622	0.96029693
13	0.03143092	0.99172783
14	0.00689837	0.99862617
15	0.00116412	0.99979025
16	0.00015804	0.99994826
	D_1	D_2

TABLE D.10

```
                    **********COMPONENT/EQUIPMENT REQUIREMENTS**********

EQUIPMENT NAME BARBARA          COMPONENT NAME LITTLE BARBARA    FUNCTION CODE 35123456789 11
                            UTIL RATE 1.0000   FAILURE ARGUMENT HOURS

   NUMBER OF COMPONENTS IN EQUIPMENT                              1.

   MAXIMUM SPARES                                                 0

                    **********COMPONENT LIFE CHARACTERISTICS**********

   NUMBER OF FAILURE MODES        2

NUMBER OF FAILURE STAGES=    2 FOR MODE     1     CRITICALITY=    2
STAGE    1     USES CURVE NO.    11            CURVE 11  BARBARA
                    STAGE 1   BARBARA                     WEIBUL    A=  0.330529E-08 B= 2.7801  MU=    1000.00 P(MU/2)= 0.9000
STAGE    2     USES CURVE NO.    12            CURVE 12  BARBARA
                    STAGE 2   BARBARA                     WEIBUL    A=  0.200000E-02 B= 1.0000  MU=     500.00 P(MU/2)= 0.6066
                                                                                1/4 MU=           375.0000      P=   0.89202
                                                                                1/2 MU=           750.0000      P=   0.91217
                                                                                3/4 MU=          1125.0000      P=   0.70695
                                                                                    MU=          1500.0000      P=   0.44250
                                                                                3/2 MU=          2250.0000      P=   0.11255
                                                                                  2 MU=          3000.0000      P=   0.02517
NUMBER OF FAILURE STAGES=    1 FOR MODE     2     CRITICALITY=    1                                   A
STAGE    1     USES CURVE NO.    13            CURVE 13  BARBARA
                    STAGE 1   BARBARA                     WEIBUL    A=  0.613195E-19 B= 5.9876  MU=    1500.00 P(MU/2)= 0.9900

                    **********MAINTENANCE FREQUENCY CHARACTERISTICS**********

   PROBABILITY OF NO PREVENTIVE MAINTENANCE WITH COMPONENT USE(BETA)
                                                           USES CURVE NO.      8 CURVE 8    BARBARA
                    BETA      BARBARA                     WEIBUL    A=  0.330529E-08 B= 2.7801  MU=    1000.00 P(MU/2)= 0.9000

   PROBABILITY OF INITIATING PREVENTIVE MAINTENANCE WITH COMPONENT USE(GAMMA1)
                                                           USES CURVE NO.      9 CURVE 9    BARBARA
                    GAMMA1    BARBARA                     WEIBUL    A=  0.330529E-08 B= 2.7801  MU=    1000.00 P(MU/2)= 0.9000

   PROBABILITY OF COMPLETING PREVENTIVE MAINTENANCE(GAMMA2)=  0.792256
                                                           USES CURVE NO.     10 CURVE 10   BARBARA

   PROBABILITY OF HANDLING/TRANSPORTATION FAILURE(1-DELTA)=  0.0

   PROBABILITY OF COMPLETING CORRECTIVE MAINTENANCE FOLLOWING MISSION FAILURE(ALPHA)=  0.999903
                                                           USES CURVE NO.      7 CURVE 7    BARBARA

                    **********COST AND HOURS DATA**********

COST PER SERVICE MAN HOUR                          11.60
COST PER PM MAN HOUR                               11.60
COST PER CM MAN HOUR FOR H/T                       11.60
MATERIAL COST PER SERVICE                         100.00
MATERIAL COST PER PM                             1000.00
MATERIAL COST PER CM FOR H/T                     2000.00
COST UNAVAILABLE                                 2000.00
COST UNRELIABLE                                 50000.00
MAN HOURS PER SERVICE                               1.00
MAN HOURS PER PM                                   10.00
```

TABLE D.10 (cont)

MAN HOURS PER H/T FAILURE			10.00
MAN HOURS PER MISSION FAILURE(NOT USED)			0.0
OPERATING INTERVAL PER SERVICE ACTION			20.00
COST PER CM MAN HOUR BY MODE	11.600	11.600	
MATERIAL COST PER CM BY MODE	2000.000	2000.000	
MAN HOURS MISS FAIL BY MODE	10.000	10.000	

MISSION	USAGE	SURVIVAL	PREVENTIVE MAINTENANCE NONE	COMPLETE	INCOMPLETE	MODE INTEGRALS	
1	100.00	0.999939	0.998800	0.000951	0.000249	0.0001	0.0000
2	200.00	0.999194	0.991786	0.006508	0.001706	0.0007	0.0
3	300.00	0.996403	0.974858	0.019919	0.005223	0.0028	0.0000
4	400.00	0.989712	0.944917	0.043640	0.011443	0.0065	0.0002
5	500.00	0.976942	0.899998	0.079227	0.020775	0.0121	0.0006
6	600.00	0.955744	0.839530	0.127133	0.033337	0.0195	0.0017
7	700.00	0.923765	0.764527	0.186555	0.048918	0.0282	0.0038
8	800.00	0.878863	0.677603	0.255421	0.066976	0.0376	0.0073
9	900.00	0.819399	0.582761	0.330560	0.086679	0.0466	0.0128
10	1000.00	0.744641	0.484934	0.408064	0.107002	0.0542	0.0205
11	1100.00	0.655230	0.389327	0.483809	0.126864	0.0592	0.0302
12	1200.00	0.553706	0.300746	0.553988	0.145266	0.0606	0.0410
13	1300.00	0.444824	0.222919	0.615647	0.161434	0.0578	0.0511
14	1400.00	0.335477	0.158130	0.666977	0.174894	0.0509	0.0584
15	1500.00	0.233869	0.107068	0.707431	0.185501	0.0410	0.0606
16	1600.00	0.147860	0.069017	0.737577	0.193406	0.0298	0.0562
17	1700.00	0.082839	0.042248	0.758785	0.198967	0.0191	0.0459
18	1800.00	0.039986	0.024498	0.772847	0.202655	0.0106	0.0323
19	1900.00	0.016076	0.013423	0.781621	0.204956	0.0049	0.0190
20	2000.00	0.005170	0.006932	0.786764	0.206304	0.0019	0.0090
21	2100.00	0.001268	0.003367	0.789588	0.207045	0.0006	0.0034
22	2200.00	0.000224	0.001534	0.791041	0.207425	0.0001	0.0009
23	2300.00	0.000027	0.000654	0.791738	0.207608	0.0000	0.0002
		B_1	B_2	B_3	B_4		

TABLE D.10 (Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT BARBARA FUNCTION CODE 351234567890 11 STATISTICS FOR MISSIONS 1 COMPONENT(S)

EXPECTED MAINTENANCE ACTIONS BY TYPE

MISSIONS	SERVICE ACTIONS	COMPLETE PMA'S	INCOMPLET PMA'S	COMPLETE CMA'S	INCOMPLET CMA'S	HAND/TRA CMA'S	MIS FAIL CMA'S	COMPLETE MA'S	INCOMPLET MA'S	TOTAL MA'S
1	5.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.00
2	10.00	0.01	0.00	0.00	0.00	0.0	0.00	0.01	0.00	0.01
3	15.00	0.03	0.00	0.00	0.00	0.0	0.00	0.03	0.00	0.03
4	20.00	0.07	0.01	0.01	0.00	0.0	0.01	0.08	0.01	0.09
5	25.00	0.14	0.02	0.02	0.00	0.0	0.02	0.16	0.02	0.18
6	30.00	0.24	0.04	0.04	0.00	0.0	0.04	0.28	0.04	0.32
7	35.00	0.36	0.06	0.06	0.00	0.0	0.06	0.43	0.06	0.49
8	40.00	0.49	0.10	0.09	0.00	0.0	0.09	0.58	0.10	0.67
9	45.00	0.60	0.13	0.11	0.00	0.0	0.11	0.71	0.13	0.84
25	125.00	2.01	0.50	0.39	0.00	0.0	0.39	2.41	0.50	2.91

TABLE D.10 (Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT BARBARA   FUNCTION CODE 35123456789 11   COST STATISTICS FOR MISSIONS 1 COMPONENT(S)

MISS-	****SERVICE ACTION*****			***PREVENTIVE MAINT****			***CORRECTIVE MAINT****			*******TOTAL*********			UNAVAIL-	UNRELI-
IONS	LABOR	MATERIAL	TOTAL	LABOR	MATERIAL	TOTAL	LABOR	MATERIAL	TOTAL	LABOR	MATERIAL	TOTAL	ABLE	ABLE
1	58.	500.	558.	0.	1.	1.	0.	0.	0.	58.	501.	559.	0.	3.
2	116.	1000.	1116.	1.	8.	9.	0.	2.	2.	117.	1009.	1126.	0.	40.
3	174.	1500.	1674.	3.	29.	32.	0.	7.	8.	178.	1536.	1714.	4.	179.
4	232.	2000.	2232.	9.	76.	85.	1.	20.	21.	242.	2096.	2338.	14.	502.
5	290.	2500.	2790.	18.	158.	176.	3.	43.	46.	311.	2701.	3012.	36.	1087.
6	348.	3000.	3348.	32.	278.	310.	5.	79.	83.	385.	3356.	3741.	73.	1966.
7	406.	3500.	3906.	49.	426.	476.	7.	124.	131.	463.	4050.	4513.	126.	3093.
8	464.	4000.	4464.	68.	585.	652.	10.	173.	183.	542.	4758.	5300.	191.	4334.
9	522.	4500.	5022.	85.	729.	814.	13.	221.	233.	619.	5450.	6069.	257.	5514.
25	1450.	12500.	13950.	292.	2516.	2808.	46.	786.	831.	1787.	15802.	17590.	1007.	19647.

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

COMPONENT   LITTLE BARBARA   FUNCTION CODE 35123456789 11 IS USED   2 TIME(S) ON   25 MISSION(S) WITH   9 SPARE(S) MAX

SPARES	PROBABILITY	CUM PROBABILITY
3	0.00015480	0.00015480
4	0.05596001	0.05611481
5	0.29445070	0.35056549
6	0.45255291	0.80311841
7	0.16984844	0.97296685
8	0.02527591	0.99824274
9	0.00167717	0.99991989
	D_1	D_2

TABLE D.11

```
**********COMPONENT/EQUIPMENT REQUIREMENTS**********

EQUIPMENT NAME CHLOE          COMPONENT NAME LITTLE CHLOE      FUNCTION CODE 36123456789 12
                       UTIL RATE 0.7500   FAILURE ARGUMENT HOURS

    NUMBER OF COMPONENTS IN EQUIPMENT                          10.

    MAXIMUM SPARES                                              0

                        **********COMPONENT LIFE CHARACTERISTICS**********

    NUMBER OF FAILURE MODES         1

NUMBER OF FAILURE STAGES=    1 FOR MODE     1     CRITICALITY=    1
STAGE    1     USES CURVE NO.    18           CURVE 18   CHLOE
                  I-VALUE     CHLOE                     WEIBUL    A=  0.131101E-22 B= 6.9671  MU=   1800.00 P(MU/2)= 0.9950
                                                                                                  A
                      **********MAINTENANCE FREQUENCY CHARACTERISTICS**********

    PROBABILITY OF NO PREVENTIVE MAINTENANCE WITH COMPONENT USE(BETA)
                                                        USES CURVE NO.    15 CURVE 15   CHLOE
                  BETA       CHLOE                      WEIBUL    A=  0.782774E-16 B= 5.0127  MU=   1500.00 P(MU/2)= 0.9800

    PROBABILITY OF INITIATING PREVENTIVE MAINTENANCE WITH COMPONENT USE(GAMMA1)
                                                        USES CURVE NO.    16 CURVE 16   CHLOE
                  GAMMA 1    CHLOE                      WEIBUL    A=  0.782774E-16 B= 5.0127  MU=   1500.00 P(MU/2)= 0.9800

    PROBABILITY OF COMPLETING PREVENTIVE MAINTENANCE(GAMMA2)=  0.917915
                                                        USES CURVE NO.    17 CURVE 17   CHLOE

    PROBABILITY OF HANDLING/TRANSPORTATION FAILURE(1-DELTA)=  0.050000


    PROBABILITY OF COMPLETING CORRECTIVE MAINTENANCE FOLLOWING MISSION FAILURE(ALPHA)=  0.993262
                                                        USES CURVE NO.    14 CURVE 14   CHLOE

                      **********COST AND HOURS DATA**********

COST PER SERVICE MAN HOUR                          11.60
COST PER PM MAN HOUR                               11.60
COST PER CM MAN HOUR FOR H/T                       11.60
MATERIAL COST PER SERVICE                         100.00
MATERIAL COST PER PM                             1000.00
MATERIAL COST PER CM FOR H/T                     2000.00
COST UNAVAILABLE                                 2000.00
COST UNRELIABLE                                 50000.00
MAN HOURS PER SERVICE                               1.00
MAN HOURS PER PM                                   10.00
MAN HOURS PER H/T FAILURE                          10.00
MAN HOURS PER MISSION FAILURE(NOT USED)             0.0
OPERATING INTERVAL PER SERVICE ACTION              20.00

COST PER CM MAN HOUR BY MODE      11.600
MATERIAL COST PER CM BY MODE    2000.000
MAN HOURS MISS FAIL BY MODE       10.000

                              PREVENTIVE MAINTENANCE
  MISSION      USAGE   SURVIVAL   NONE     COMPLETE INCOMPLETE  NONE INTEGRALS
```

TABLE D.11 (Cont)

		B_1	B_2	B_3	B_4	
1	75.00	1.000000	1.000000	0.000000	0.000000	0.0000
2	150.00	1.000000	0.999994	0.000006	0.000001	0.0000
3	225.00	1.000000	0.999952	0.000044	0.000004	0.0000
4	300.00	0.999998	0.999795	0.000188	0.000017	0.0000
5	375.00	0.999989	0.999374	0.000574	0.000051	0.0000
6	450.00	0.999960	0.998440	0.001432	0.000128	0.0000
7	525.00	0.999883	0.996625	0.003058	0.000277	0.0001
8	600.00	0.999703	0.993419	0.006049	0.000540	0.0002
9	675.00	0.999325	0.988155	0.010872	0.000972	0.0004
10	750.00	0.998594	0.979997	0.018361	0.001642	0.0007
11	825.00	0.997270	0.967944	0.029425	0.002631	0.0013
12	900.00	0.995000	0.950853	0.045113	0.004034	0.0023
13	975.00	0.991284	0.927489	0.066559	0.005952	0.0037
14	1050.00	0.985437	0.896606	0.094907	0.008487	0.0058
15	1125.00	0.976555	0.857073	0.131195	0.011732	0.0089
16	1200.00	0.963489	0.808038	0.176205	0.015757	0.0131
17	1275.00	0.944837	0.749132	0.230275	0.020593	0.0187
18	1350.00	0.918971	0.680675	0.293113	0.026212	0.0259
19	1425.00	0.884125	0.603854	0.363628	0.032518	0.0348
20	1500.00	0.838569	0.520835	0.439833	0.039332	0.0456
21	1575.00	0.780880	0.434716	0.518882	0.046401	0.0577
22	1650.00	0.710339	0.349296	0.597291	0.053413	0.0705
23	1725.00	0.627403	0.268642	0.671324	0.060034	0.0829
24	1800.00	0.534152	0.196527	0.737519	0.065953	0.0932
25	1875.00	0.434564	0.135828	0.793237	0.070936	0.0996

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TABLE D.11 (Cont)

FAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT CHLOE FUNCTION CODE 36123456789 12 STATISTICS FOR MISSIONS TO COMPONENT(S)

EXPECTED MAINTENANCE ACTIONS BY TYPE

MISSIONS	SERVICE ACTIONS	COMPLETE PMA'S	INCOMPLET PMA'S	COMPLETE CMA'S	INCOMPLET CMA'S	HAND/TRA CMA'S	MIS FAIL CMA'S	COMPLETE MA'S	INCOMPLET MA'S	TOTAL MA'S
1	50.00	0.00	0.0	0.49	0.00	0.50	0.0	0.49	0.00	0.50
2	100.00	0.00	0.00	0.99	0.01	1.00	0.0	0.99	0.01	1.00
3	150.00	0.00	0.00	1.49	0.01	1.50	0.00	1.49	0.01	1.50
4	200.00	0.00	0.00	1.98	0.01	2.00	0.00	1.98	0.01	2.00
5	250.00	0.01	0.00	2.48	0.02	2.50	0.00	2.49	0.02	2.50
6	300.00	0.02	0.00	2.98	0.02	3.00	0.00	2.99	0.02	3.01
7	350.00	0.04	0.00	3.47	0.02	3.50	0.00	3.51	0.03	3.54
8	400.00	0.08	0.00	3.97	0.03	4.00	0.00	4.05	0.03	4.06
9	450.00	0.15	0.01	4.47	0.03	4.49	0.00	4.62	0.04	4.66
25	1250.00	5.75	0.49	12.81	0.09	12.47	0.43	18.56	0.58	19.14

TABLE D.11 (Cont)

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT CHLCF   FUNCTION CODE 36123456789 12   COST STATISTICS FOR MISSIONS TO COMPONENT(S)

MISS-IONS	****SERVICE ACTION***** LABOR	MATERIAL	TOTAL	***PREVENTIVE MAINT**** LABOR	MATERIAL	TOTAL	***CORRECTIVE MAINT**** LABOR	MATERIAL	TOTAL	*******TOTAL********* LABOR	MATERIAL	TOTAL	UNAVAIL-ABLE	UNRELI-ABLE
1	580.	5000.	5580.	0.	0.	0.	58.	993.	1051.	638.	5993.	6631.	7.	0.
2	1160.	10000.	11160.	0.	0.	0.	116.	1993.	2109.	1276.	11993.	13269.	13.	0.
3	1740.	15000.	16740.	0.	0.	0.	174.	2993.	3166.	1914.	17993.	19907.	20.	0.
4	2320.	20000.	22320.	0.	2.	2.	232.	3992.	4224.	2552.	23994.	26546.	27.	1.
5	2900.	25000.	27900.	1.	7.	7.	290.	4992.	5282.	3190.	29999.	33189.	34.	4.
6	3480.	30000.	33480.	2.	18.	20.	348.	5992.	6340.	3830.	36010.	39840.	42.	15.
7	4060.	35000.	39060.	5.	41.	46.	406.	6993.	7399.	4470.	42035.	46505.	50.	43.
8	4640.	40000.	44640.	10.	85.	95.	464.	7995.	8458.	5114.	48080.	53193.	61.	134.
9	5220.	45000.	50220.	19.	160.	179.	522.	8999.	9521.	5761.	54159.	59920.	75.	226.
25	14500.	125000.	139500.	724.	6238.	6961.	1496.	25801.	27298.	16720.	157039.	173759.	1157.	21651.

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

COMPONENT   LITTLE CHLCF   FUNCTION CODE 36123456789 12 IS USED   20 TIME(S) IN   25 MISSION(S) WITH [illegible] SPARE(S) MAX

SPARES	PROBABILITY	CUM PROBABILITY
26	0.00032490	0.00032490
27	0.00094813	0.00127303
28	0.00239434	0.00366737
29	0.00531705	0.00898442
30	0.01051605	0.01950048
31	0.01871680	0.03821728
32	0.03023786	0.06845510
33	0.04466613	0.11312121
34	0.06070612	0.17382729
35	0.07632673	0.25015402
36	0.08920449	0.33935851
37	0.09732014	0.43667865
38	0.09948725	0.53616589
39	0.09562272	0.63178861
40	0.08668047	0.71846908
41	0.07431340	0.79278249
42	0.06041050	0.85319299
43	0.04667453	0.89986748
44	0.03434893	0.93421638
45	0.02412596	0.95834231
46	0.01620332	0.97454563
47	0.01042377	0.98496932
48	0.00643354	0.99140280
49	0.00381538	0.99521816
50	0.00217721	0.99739534
51	0.00119707	0.99859233
52	0.00063495	0.99922729
53	0.00032528	0.99955255
54	0.00016113	0.99971366
	D_1	D_2

TABLE D.12

RAM APSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

SYSTEM SUPPORT COST   2 SYSTEM(S)

MISS-IONS	****SERVICE ACTION***** LABOR	MATERIAL	TOTAL	***PREVENTIVE MAINT**** LABOR	MATERIAL	TOTAL	***CORRECTIVE MAINT**** LABOR	MATERIAL	TOTAL	********TOTAL********* LABOR	MATERIAL	TOTAL	UNAVAIL-ABIL	UNRELI-ABIL
1	1508.	13000.	14508.	0.	2.	2.	125.	2147.	2271.	1633.	15149.	16781.	13.	6.
2	3016.	26000.	29016.	2.	16.	18.	250.	4309.	4559.	3268.	33325.	33593.	28.	81.
3	4524.	39000.	43524.	8.	66.	73.	376.	6479.	6855.	4907.	45545.	50453.	48.	359.
4	6032.	52000.	58032.	22.	187.	209.	503.	8665.	9168.	6556.	60852.	67408.	82.	1315.
5	7540.	65000.	72540.	53.	432.	483.	631.	10872.	11503.	8221.	76305.	84526.	141.	2220.
6	9041.	78000.	87048.	100.	865.	965.	760.	13106.	13866.	9908.	91971.	101879.	231.	4080.
7	10556.	91000.	101556.	179.	1545.	1724.	891.	15365.	16256.	11626.	107909.	119536.	357.	6570.
8	12064.	104000.	116064.	290.	2498.	2788.	1023.	17641.	18665.	13377.	124140.	137517.	511.	9514.
9	13572.	117000.	130572.	426.	3669.	4094.	1156.	19925.	21080.	15153.	140593.	155746.	679.	12633.
25	37700.	325000.	362700.	2965.	25564.	28529.	3330.	57414.	60744.	43995.	407977.	451972.	4432.	88637.

TABLE D.13

RAP APSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EXPECTED TOTAL SYSTEM MAINTENANCE ACTIONS BY TYPE 2 SYSTEM(S)

MISSIONS	SERVICE ACTIONS	TOTAL MA'S	COMPLETE MA'S	INCOMPLET MA'S	TOTAL PMA'S	COMPLETE PMA'S	INCOMPLET PMA'S	TOTAL CMA'S	COMPLETE CMA'S	INCOMPLET CMA'S	HAND/TLA CMA'S	MIS FAIL CMA'S
1	130.00	1.08	1.07	0.01	0.00	0.00	0.0	1.07	1.07	0.01	1.07	0.00
2	260.00	2.17	2.16	0.01	0.02	0.02	0.00	2.15	2.14	0.01	2.15	[illegible]
3	390.00	3.31	3.28	0.02	0.07	0.06	0.00	3.24	3.22	0.02	3.23	0.01
4	520.00	4.52	4.48	0.04	0.19	0.17	0.01	4.33	4.31	0.03	4.31	0.02
5	650.00	5.87	5.80	0.07	0.43	0.40	0.04	5.44	5.40	0.03	5.39	0.04
6	780.00	7.42	7.30	0.12	0.86	0.79	0.08	6.55	6.51	0.04	6.47	0.08
7	910.00	9.23	9.05	0.18	1.54	1.41	0.13	7.68	7.64	0.05	7.55	0.13
8	1040.00	11.32	11.06	0.26	2.50	2.30	0.20	8.82	8.77	0.05	8.63	0.19
9	1170.00	13.63	13.29	0.34	3.67	3.39	0.28	9.96	9.90	0.06	9.71	0.25
25	3250.00	54.27	52.05	2.22	25.56	23.52	2.04	28.71	28.53	0.17	26.93	1.77

TABLE D.14

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

SYSTEM COST FOR CORRECTIVE MAINTENANCE BY CRITICALITY 2 SYSTEM(S)

	MISSIONS	HAND/TRA	CRIT 1	CRIT 2
LABOR	1	124.	0.	0.
MATERIAL		2147.	0.	0.
TOTAL		2271.	0.	0.
LABOR	2	250.	0.	0.
MATERIAL		4306.	0.	3.
TOTAL		4555.	0.	3.
LABOR	3	375.	0.	1.
MATERIAL		6465.	0.	14.
TOTAL		6840.	0.	15.
LABOR	4	500.	0.	2.
MATERIAL		8624.	1.	40.
TOTAL		9125.	1.	42.
LABOR	5	625.	0.	5.
MATERIAL		10784.	4.	95.
TOTAL		11409.	4.	90.
LABOR	6	751.	1.	9.
MATERIAL		12943.	10.	153.
TOTAL		13694.	11.	162.
LABOR	7	876.	1.	14.
MATERIAL		15102.	23.	240.
TOTAL		15978.	24.	254.
LABOR	8	1001.	3.	20.
MATERIAL		17261.	43.	337.
TOTAL		18262.	46.	357.
LABOR	9	1126.	4.	25.
MATERIAL		19419.	72.	434.
TOTAL		20546.	76.	459.
LABOR	25	3124.	115.	91.
MATERIAL		53868.	1980.	1565.
TOTAL		56993.	2095.	1656.

TABLE D.15

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EXPECTED TOTAL SYSTEM MAINTENANCE ACTIONS BY CRITICALITY   2 SYSTEM(S)

MISSIONS	MIS FAIL CMA'S	CRIT 1	CRIT 2
1	0.00	0.00	0.00
2	0.00	0.00	0.00
3	0.01	0.00	0.01
4	0.02	0.00	0.02
5	0.04	0.00	0.04
6	0.08	0.01	0.08
7	0.13	0.01	0.12
8	0.19	0.02	0.17
9	0.25	0.04	0.22
25	1.77	0.99	0.78

TABLE D. 16

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT ANNA FUNCTION CODE 52123456789 1) STATISTICS FOR MISSIONS 2 COMPONENT(S)

EXPECTED CORRECTIVE MAINTENANCE ACTIONS BY FAILURE MODE

MISSIONS	HAND/TRA	MODE 1
1	0.04	0.00
2	0.08	0.00
3	0.12	0.00
4	0.16	0.00
5	0.20	0.00
6	0.24	0.00
7	0.28	0.00
8	0.32	0.01
9	0.36	0.01
25	1.00	0.06

TABLE D.17

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT BARBARA FUNCTION CODE 35123456789 11 STATISTICS FOR MISSIONS 1 COMPONENT(S)

EXPECTED CORRECTIVE MAINTENANCE ACTIONS BY FAILURE MODE

MISSIONS	HADO/IRA	MODE 1	MODE 2
1	0.0	0.00	0.00
2	0.0	0.00	0.00
3	0.0	0.00	0.00
4	0.0	0.01	0.00
5	0.0	0.02	0.00
6	0.0	0.04	0.00
7	0.0	0.06	0.00
8	0.0	0.09	0.01
9	0.0	0.13	0.01
25	0.0	0.33	0.06

TABLE D.18

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT CHECK FUNCTION CODE 36123456789 12 STATISTICS FOR MISSIONS TO COMPONENTS

EXPECTED CORRECTIVE MAINTENANCE ACTIONS BY FAILURE MODE

MISSIONS	HARD/TRA	MODE 1
1	0.50	0.00
2	1.00	0.00
3	1.50	0.00
4	2.00	0.00
5	2.50	0.00
6	3.00	0.00
7	3.50	0.00
8	4.00	0.00
9	4.49	0.00
25	12.47	0.43

TABLE D.19

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT ANNA FUNCTION CODE 52123456789 13 STATISTICS FOR MISSIONS 2 COMPONENT(S)

EXPECTED CORRECTIVE MAINTENANCE ACTIONS BY CRITICALITY CODE

MISSIONS	MIS FAIL CMA'S	CODE 1	CODE 2
1	0.00	0.0	0.00
2	0.00	0.0	0.00
3	0.00	0.0	0.00
4	0.00	0.0	0.00
5	0.00	0.0	0.00
6	0.00	0.0	0.00
7	0.00	0.0	0.00
8	0.01	0.0	0.01
9	0.01	0.0	0.01
25	0.06	0.0	0.06

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT BARBARA FUNCTION CODE 35123456789 11 STATISTICS FOR MISSIONS 1 COMPONENT(S)

EXPECTED CORRECTIVE MAINTENANCE ACTIONS BY CRITICALITY CODE

MISSIONS	MIS FAIL CMA'S	CODE 1	CODE 2
1	0.00	0.00	0.00
2	0.00	0.00	0.00
3	0.00	0.00	0.00
4	0.01	0.00	0.01
5	0.02	0.00	0.02
6	0.04	0.00	0.04
7	0.06	0.00	0.06
8	0.09	0.01	0.08
9	0.11	0.01	0.10
25	0.39	0.06	0.33

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT CHLOE FUNCTION CODE 36123456789 12 STATISTICS FOR MISSIONS 13 COMPONENT(S)

EXPECTED CORRECTIVE MAINTENANCE ACTIONS BY CRITICALITY CODE

MISSIONS	MIS FAIL CMA'S	CODE 1	CODE 2
1	0.0	0.00	0.0
2	0.0	0.00	0.0
3	0.00	0.00	0.0
4	0.00	0.00	0.0
5	0.00	0.00	0.0
6	0.00	0.00	0.0
7	[illegible]	[illegible]	[illegible]

TABLE D.19 (Cont)

8	0.00	0.00	0.0
9	0.00	0.00	0.0
25	0.43	0.43	0.0

TABLE D.20

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT ANNA FUNCTION CODE 52123456789 10 COST STATISTICS FOR MISSIONS BY FAILURE MODE 2 COMPONENT(S)

	MISSIONS	HAND/TRA	MODE 1
LABOR	1	5.	0.
MATERIAL		80.	0.
TOTAL		85.	0.
LABOR	2	9.	0.
MATERIAL		160.	0.
TOTAL		169.	0.
LABOR	3	14.	0.
MATERIAL		240.	0.
TOTAL		254.	0.
LABOR	4	19.	0.
MATERIAL		320.	0.
TOTAL		339.	0.
LABOR	5	23.	0.
MATERIAL		400.	1.
TOTAL		423.	1.
LABOR	6	28.	0.
MATERIAL		480.	2.
TOTAL		508.	2.
LABOR	7	32.	0.
MATERIAL		560.	6.
TOTAL		592.	6.
LABOR	8	37.	1.
MATERIAL		640.	13.
TOTAL		677.	14.
LABOR	9	42.	1.
MATERIAL		720.	23.
TOTAL		762.	24.
LABOR	25	116.	7.
MATERIAL		1999.	121.
TOTAL		2115.	128.

TABLE D.21

RAM AMSEC PRELIMINARY TRIAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT BARBARA   FUNCTION CODE 35123456789 11 COST STATISTICS FOR MISSIONS BY FAILURE MODE   1 COMPONENT(S)

	MISSIONS	HAND/TRA	MODE 1	MODE 2
LABOR	1	0.	0.	0.
MATERIAL		0.	0.	0.
TOTAL		0.	0.	0.
LABOR	2	0.	0.	0.
MATERIAL		0.	2.	0.
TOTAL		0.	2.	0.
LABOR	3	0.	0.	0.
MATERIAL		0.	7.	0.
TOTAL		0.	7.	0.
LABOR	4	0.	1.	0.
MATERIAL		0.	20.	0.
TOTAL		0.	21.	0.
LABOR	5	0.	2.	0.
MATERIAL		0.	42.	2.
TOTAL		0.	44.	2.
LABOR	6	0.	4.	0.
MATERIAL		0.	74.	4.
TOTAL		0.	79.	5.
LABOR	7	0.	7.	1.
MATERIAL		0.	114.	10.
TOTAL		0.	121.	10.
LABOR	8	0.	9.	1.
MATERIAL		0.	156.	17.
TOTAL		0.	165.	18.
LABOR	9	0.	11.	2.
MATERIAL		0.	194.	27.
TOTAL		0.	205.	28.
LABOR	25	0.	38.	7.
MATERIAL		0.	662.	124.
TOTAL		0.	700.	131.

TABLE D.22

RAM AMSEC PRELIMINARY TOTAL RUN FOR ILLUSTRATIVE SAMPLE

EQUIPMENT CHLOE   FUNCTION CODE 36123456789 12 COST STATISTICS FOR MISSIONS BY FAILURE MODE 10 COMPONENT(S)

	MISSIONS	HAND/TRA	MODE 1
LABOR	1	58.	0.
MATERIAL		993.	0.
TOTAL		1051.	0.
LABOR	2	116.	0.
MATERIAL		1993.	0.
TOTAL		2108.	0.
LABOR	3	174.	0.
MATERIAL		2993.	0.
TOTAL		3166.	0.
LABOR	4	232.	0.
MATERIAL		3992.	0.
TOTAL		4224.	0.
LABOR	5	290.	0.
MATERIAL		4992.	0.
TOTAL		5281.	0.
LABOR	6	348.	0.
MATERIAL		5991.	1.
TOTAL		6339.	1.
LABOR	7	405.	0.
MATERIAL		6991.	2.
TOTAL		7397.	2.
LABOR	8	463.	0.
MATERIAL		7990.	4.
TOTAL		8454.	4.
LABOR	9	521.	1.
MATERIAL		8990.	9.
TOTAL		9511.	10.
LABOR	25	1446.	50.
MATERIAL		24935.	866.
TOTAL		26381.	916.

TABLE D.23. FLAGGED REFERENCES FROM TABLES D.3-TABLE D.12

A	Composite two stage life characteristic (single mode) Argument vs. probability of mode survival
B-1	Composite component life characteristics (all modes) Argument vs. probability of survival
B-2	Probability of no PM with component age Argument vs. probability PM
B-3	Probability of complete PM with component age Argument vs. probability PM is initiated and completed
B-4	Probability of incomplete PM with component age Argument vs. probability PM is initiated and not completed
C-1	Accomplish probability regarding i^{th} mission i=1,2, etc. that component/equipment/system is ready and functions as required throughout mission
C-2	Readiness-probability regarding i^{th} mission i=1,2, etc. that component/equipment/system is operable at start of mission
C-3	Reliability-probability regarding i^{th} mission that component/equipment/system functions as required throughout mission given that it is ready
C-4	Average component/equipment/system accomplish, readiness, and reliability equate to running averages of individual mission probabilities, viz, Av P over ν mission = $\sum_{i=1}^{\nu} P_i$ where P_i represents i^{th} mission probability of accomplishment, readiness, or reliability.
D-1	Spares probability, lists probability that exactly W spares will be consumed by h systems operating over ν mission
D-2	Spares cum probability, cumulates D-1 probabilities and equates to probability W or less spares will be consumed by h system operating over ν missions.

LME